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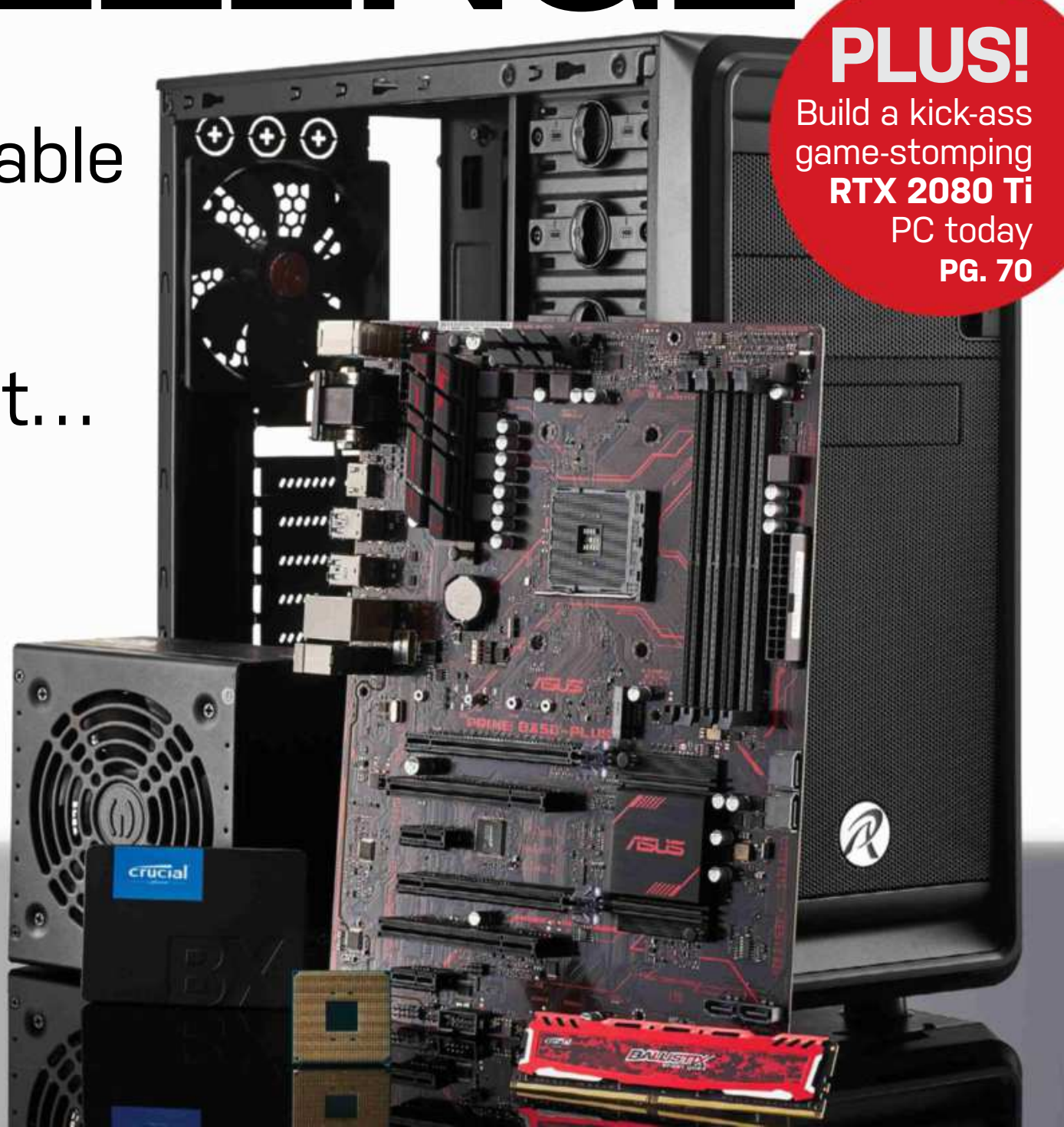

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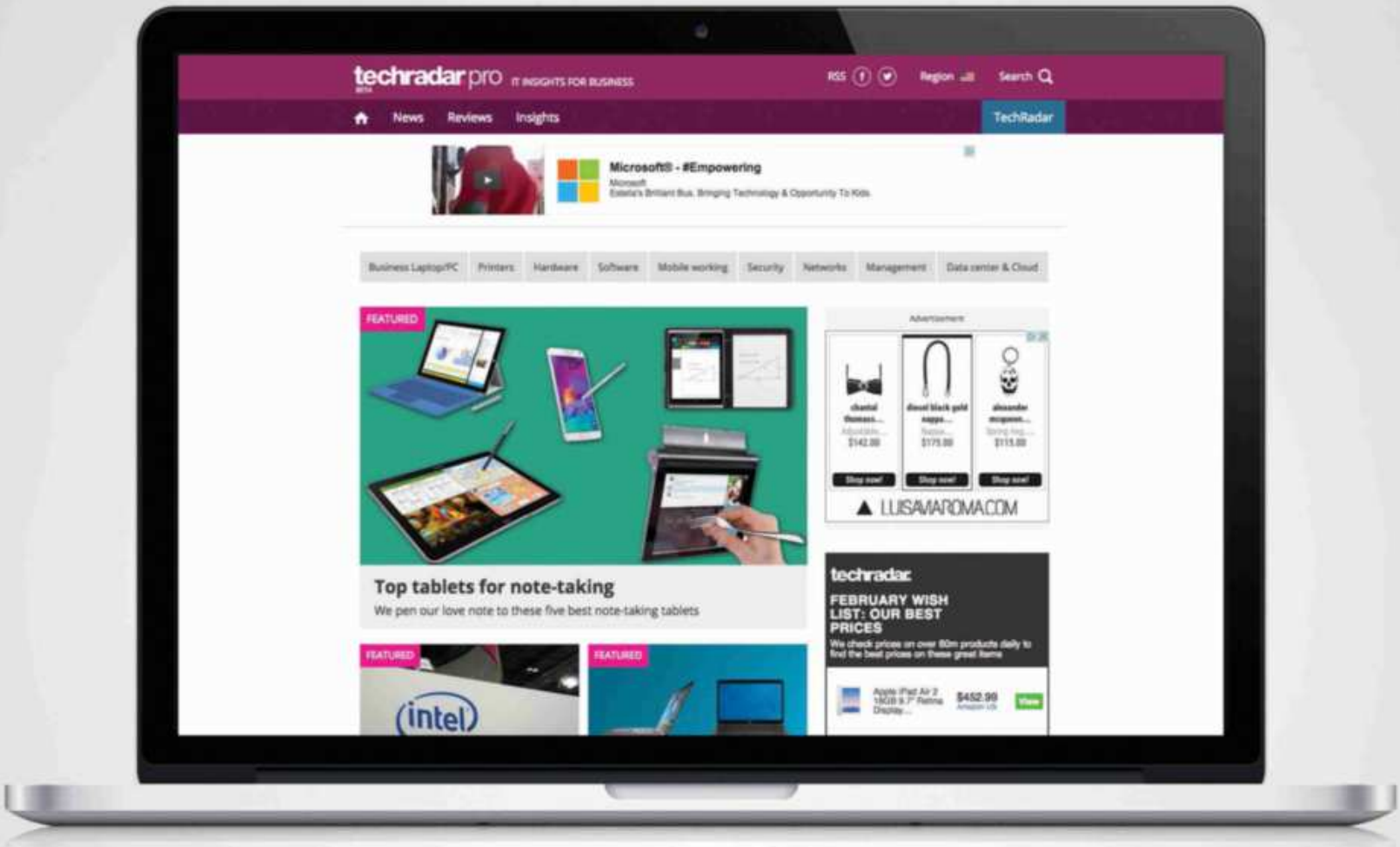

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Alan Dexter

THERE ARE BARGAINS TO BE HAD EVEN AT THE CUTTING EDGE

THIS ISSUE, we feature two very different types of build. Turn to page 70, and you'll find a traditional *Maximum PC* system that uses the latest, high-end parts, including the current graphics card of the moment, the GeForce RTX 2080 Ti. Those turning to page 26 will find a very different kind of build, though, one that focuses on trying to bring the overall ticket price in at under $300—no easy ask, especially given the skyrocketing prices we're seeing with the latest hardware releases.

Amazingly, this budget build is constructed around a new release as well; this time in the form of the Athlon 200GE. Apart from a welcome return of the much-loved Athlon branding, it also represents a renewed focus on the often overlooked budget end of the PC building spectrum, as it rolls in at a pleasing $55. That nets you a dual-core processor with SMT, which means it can handle four threads at once, and you get Radeon Vega integrated graphics, too, all with a total TDP of just 35W. It's a great CPU, and thanks to those three Vega cores, it means you can forego dropping money on a graphics card—unless, of course, you've got your sights set on some serious gaming, but then a budget build may not be for you. That machine toward the back of the magazine is probably more up your street, although it does cost 10 times as much.

In order to get the budget build price in so low, we've had to omit one important piece of the puzzle. A piece that many of you feel you can't live without: Windows. When you're dropping over $3K on a new system, the $100 you need to drop on the OS is no big shakes, but it takes on a different aspect when that would be a quarter of the overall system price. Which is why we've recommended running Linux on it. Not a big problem, given what the machine is capable of, and if you really can't live without Microsoft's latest, there's nothing to stop you installing it on here anyway (in fact, we installed Windows 10 on it for our benchmarking suite anyway).

This brings us to a key point of any build you see in *Maximum PC*—choice. If you want to do things differently, by all means please do. These are suggestions. Frameworks for your own builds. We know these work, because we've built them, and show you how to get around any little problems in the process, but if you fancy slotting in more RAM, a better graphics card, or more storage, feel free. And let us know how you get on, because your particular build may be of interest to your fellow readers.

Alan Dexter is Maximum PC's *executive editor and a punisher of hardware. He's been a tech journalist for over 20 years, and has no problem upsetting the PC industry as a whole.*

↘ submit your questions to: comments@maximumpc.com

THE NEWS

Intel vs. AMD: Fight at the Top

AMD and Intel are both about to release halo chips

THERE IS YET another processor fight brewing, but this time around, the battle is potentially going to be a little different. It's at the top of the market, as our two contenders each release top-of-the-range desktop processors.

AMD's Ryzen has been giving Intel something of a headache, because it offers some serious bang for your buck. However, there has always been one area where Intel has ruled: at the top of the tree. If you really want the best, the fastest, for gaming, you go to Intel.

Take a look at the Hall of Fame for 3DMark. You have to scroll all the way down to fiftieth position before you reach anything other than Intel's finest. No matter how impressive AMD's chips get, the Intel fanboy can always counter with the boast of absolute superiority in the all-important gaming arena, even if it does come at an alarming premium. Now that we are about to see each company release its top chips, is this position about to change?

In the blue corner, from Intel, we have the Core i9-9900K. This is the first mainstream Intel chip with eight cores and 16 threads. It's based on Intel's 14nm++ process, and has a base clock of 3.6GHz, with a boost of up to the magical 5GHz figure. It also comes in a snazzy dodecahedron box. And we've got one in for review (the CPU, not the box)—turn to page 78 to find out what we make of it. It's set to launch at $530.

In the red corner, from AMD, we have the Ryzen 7 2800X. Or we are expected to have very soon, if rumors are to be believed. An "X800" version was noticeable by its absence from the second generation (2000 series) Ryzen launch. The previous Zen core had a 1800X as its top dog. This fueled speculation that AMD was holding it back to use as a counter for Intel's eight-core processor. It was even hinted at the Zen+ launch by Jim Anderson that a 2800 might follow. Recent rumors of it carrying more than eight cores are spurious, however. You want more? You go Threadripper, and use a TR4 motherboard. What we'll probably get is a faster clock. The current 2700X has a base clock of 3.7GHz, and a boost of up to 4.3GHz. The jump to that 5GHz figure would be a long one.

Can a 2800X seriously unseat the 9900K as gaming king? It would be an amazing upset, but it is an unlikely scenario, too. It will be fast, though, and it'll benchmark faster on many tasks; but that ultimate single-core focused game test—that's a tall order. Expect some fisticuffs anyway, because the two are bound to be pitched against each other by all and sundry.

Meanwhile, AMD sales are doing rather well. The company posted healthy second-quarter earnings of $1.76 billion, up from $1.11 billion last year. Ryzen's market share has been steadily climbing; it is forecasted to reach 30 percent by the year's end. It's been so good that the supply of motherboards is struggling to keep pace. Asus plans to expand production as A320 boards become hard to find.

Part of this success is due to Intel's troubles. Its 14nm foundry is working at capacity, leading to price rises and shortages across the board. It has even been forced to use 22nm production for its H310 chipset to keep supply lines healthy. Other silicon may move back, too. Intel really needs to get on with the move to 10nm. This is now expected to finally get moving by next July, with hints that production may even start in the spring. It can't come soon enough.

AMD and Intel sparring like this is hardly new, each trying to grab headlines with halo chips. AMD still offers the best price/performance option, and Intel still holds the shiny prizes. Keep fighting, though—competition is, as ever, good for us. **–CL**

> There has always been one area where Intel has ruled: at the top of the tree.

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BIGGEST FACEBOOK HACK YET

Fifty million accounts left completely open

THERE HAS BEEN another huge security breach at Facebook, the worst in its history. Engineers noticed unusual activity on September 16, worked out what was going on nine days later, and two days after that closed down the breach. Up to 50 million accounts are said to have been compromised; it is unsure for how long.

The hackers exploited an interaction between three software bugs, and the flaw dates back to July 2017, with the introduction of the "View As" feature—ironically, partially a privacy tool. Using it creates keys, called access tokens, which enable people to reconnect to their accounts without using passwords. It was these tokens that were spirited away.

Armed with a token, a hacker could pose as the account holder, and the account be laid open. The potential for mischief is alarming, although there have been no reports of tampering with posts, but there are signs of profile data being accessed.

The attack was sophisticated, and no group has been linked to it, leading to speculation about the source, including the possibility of involvement by state-sponsored groups. Facebook is working with the FBI to track the culprits, but results aren't expected quickly, if at all.

"We have a responsibility to protect your data, and if we can't, then we don't deserve to serve you," so said Mark Zuckerberg after the data harvesting by Cambridge Analytica earlier this year. On this hack he was "glad we found this, but it definitely is an issue that this happened in the first place." The lack of tangible damage has helped minimize the public relations storm; stock prices dipped, but nothing like the 18 percent drop in the summer.

Before Congress, Zuckerberg said, "We have to do a lot of work about building trust back." It appears this is still the case. With great data comes great responsibility. **–CL**

HERE COMES WI-FI 6

NEW STANDARD GETS SENSIBLE NAME

THE NEXT ITERATION of the Wi-Fi standard is to be called Wi-Fi 6. Previous standards are known largely as 802.11, followed by letters, and it isn't a logical progression. Wi-Fi 6 was known as 802.11ax before. The Wi-Fi Alliance has renamed a few others: 802.11ac is now Wi-Fi 5, and 802.11n is Wi-Fi 4. Wi-Fi 6 will bring a speed bump—prototypes reached 11Gbit/s, three times Wi-Fi 5, although real-world speeds are unlikely to reach such heights. It combines the 2.4 and 5GHz bands, and adds trickery such as Orthogonal Frequency Division Multiple Access, and 1024 QAM encoding to increase efficiency. It's also designed to cope with today's crowded Wi-Fi environment, where dozens of devices battle over the same airways. The first access points are being put in place now, with the main event, and certified hardware, due next year. **–CL**

GOOGLE TO HELP STATE TRACKING

In the proposed Chinese version, anyway

GOOGLE'S DRAGONFLY PROJECT, its customized search engine for the Chinese market, continues to attract controversy. The latest revelation is that the prototype search engine links all enquiries to user's phone numbers, so all searches are easily linked to individuals. It has also emerged that there are blacklists for censorship (including knowledge on human rights, and even "Nobel Prize"), as well as provision for falsified air pollution results.

The Chinese market is huge, and therefore lucrative, but the cost of participation includes an ethical element that some find hard to swallow, including many of Google's own employees, human rights organizations, and the White House (it has called for the project to be dropped). China is building a system of citizen surveillance second to none, and Google's participation is starting to look less like a business opportunity, and more like complicity in state control. Google has been reluctant to comment on Dragonfly, even to the Senate Intelligence Committee. **–CL**

Tech Triumphs and Tragedies

A monthly snapshot of what's good and bad in tech

TRIUMPHS

WORLD 3DMARK RECORD
Nvidia's 2080 Ti, aided by liquid nitrogen and overclocking, has set the world's highest 3DMark of 9,312 in Time Spy Extreme.

SPRAY-ON ANTENNAS
Drexil University in Philly has developed MXeme antennas that can be sprayed on any surface.

PLAYSTATION CLASSIC
The boom in mini retro consoles continues with the PlayStation. This little-bitty fellow comes with 20 games, and costs $100.

TRAGEDIES

NO TO SOLAR ROADS
Why not turn roads into long thin solar panels? Because they've proved inefficient, expensive, and unreliable.

iPHONES NOT CHARGING
A bug in iOS 12 means many iPhones and iPads don't charge while they're asleep.

WINDOWS STORE FAIL
After six years, it's still unreliable—now *Forza Horizons 4* suffers from the "infinite download" bug.

New Surface Surfaces

MICROSOFT HASN'T ALWAYS had success with hardware, but its Surface range broke the trend. The touchscreen hybrid devices are innovative and stylish, and Microsoft has announced an update to the range, bringing more power to the party.

Surface Pro 6, a two-in-one device with detachable keyboard, has new processors. It starts at $899 for a system sporting a Core i5-8250U, 128GB of storage, and 8GB of RAM. This jumps to $2,299 if you want a Core i7-8650U. Still no USB-C port, though. Surface Laptop 2, a touchscreen notebook, receives a similar bump in power. The $999 base version has 8GB of memory—double the previous version—and a Core i5 Kaby Lake dual-core processor. Still no USB-C, either. Both the Pro 6 and Laptop 2 come in a new color option: matte black. Apparently, it added 40–80 microns to the thickness, which meant having to redesign the space around all the ports. Lastly, there is the Surface Studio 2, the high-end desktop version, aimed at "creatives." This gets a Core i7-7820 and a GeForce GTX 1060 or 1070. Prices start at $3,499.

This is a modest refresh of specifications. What is completely new is the Surface headphones. These noise-canceling wireless smart cans will cost $349. They pause music or mute when you remove them, and restart when you put them back on. They also have built-in microphones, so you can summon Cortana if you must.

Juicier Surface gear is expected next year, including the Surface Hub 2 and HoloLens. Microsoft may have failed spectacularly at smartphones, but it has carved out a useful slice of the tablet and laptop segment for itself. **–CL**

The new 2018 Surface models, now available in a funky matte black.

Tiny Spy Chips in Servers?

Has the Chinese state secretly put spy chips into Supermicro servers during manufacture? Have these servers been used by major companies and even government departments? That's the alarming news in a report from *Bloomberg Businessweek*. It claims the chips were uncovered in 2015 after a breakdown of hardware on behalf of Amazon. The authorities were informed, but not the public, and a lot of servers quietly sold off. The news has been strongly denied by Apple, Amazon, Supermicro, and the Department for Homeland Security. Bloomberg says it has 17 highly placed anonymous insiders who have confirmed the story. Surely, there's more come.... **–CL**

All-In-One Gaming VR

Oculus has announced the Quest, a VR headset that purports to be the world's first all-in-one VR gaming system, no PC required. There are six degrees of freedom, a display resolution of 1600x1440 per eye, and four ultra-wide-angle sensors that track movement. It's planned for indoor use only, although you're free to wander anywhere you like, rather than stay in a defined area by your rig. Oculus is busy porting Rift games—it is hoped that there will be 50 ready by launch. All this is powered by a Qualcomm Snapdragon 835 processor, which you'll also find in a Samsung Galaxy S8. The Oculus Quest will be available in spring 2019, for $399. **–CL**

WIN 10 UPDATE DELETES YOUR FILES

Microsoft pauses release to deal with problem

EVERY UPDATE OF WINDOWS throws up a few "issues." The latest, the October 2018 update, also known as build 1809, has not proved immune. Along with a scattering of new features, we also get some new bugs. Among these is one that has caused Microsoft to pause the release altogether after only four days, which is embarrassing for Microsoft, and alarming for everybody else.

As it says on the company support pages, the release was paused as "we investigate isolated reports of users missing some files after updating." Essentially, people found themselves looking at empty folders where their personal data should be, specifically "Documents," "Pictures," "Videos," and "Music." A potentially nasty moment as you try to remember exactly when you made your last backup, and curse yourself for clicking "Check for updates."

The root cause is unclear, although early reports indicate that moving your "Documents" folder to another drive is one trigger. Luckily, the files are recoverable, but you need to run a recovery utility, such as Recuva, immediately, or risk having them overwritten and lost forever.

This sort of trouble really should be caught during beta testing (although there are forum posts that indicate this bug was known about weeks ago). We expect a bug or three to surface with any major update, but this one is a peach, with the potential to do enormous amounts of damage. No doubt, as we write, Microsoft engineers are working night and day to fix this, but for a while there, a Win 10 update was a scarier proposition than it usually is. **–CL**

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TECH TALK

Where Are the PCIe 4.0 Graphics Cards & Mobos?

It's been over a decade since PCI-SIG announced the preliminary specs for what would become PCIe 3.0, and we've been able to use Gen3 graphics cards since 2010. The PCIe 4.0 specs, targeting roughly double the bandwidth per pin of Gen3, started the next year, with working demonstrations in 2016, and the final specs were released in June 2017.

Going a step further, PCI-SIG announced the initial plans for PCIe 5.0 alongside the Gen4 final specs, targeting 32GT/s per pin. Yet we still don't have any PCIe 4.0 graphics cards or motherboards.

It's not that Gen4 solutions don't exist—IBM is shipping servers with PCIe 4.0 slots—but on the consumer side, not even Nvidia's Turing architecture supports Gen4. That's largely because most consumer workloads don't need the extra bandwidth. Gaming on a Gen3 x8 slot causes almost no loss in performance, and with SLI and CrossFire seeing less support and use, we've been resting on the 8GT/s plateau for years.

I said "most" consumer workloads, as there are areas where we'd benefit from Gen4's added bandwidth. Intel's mainstream consumer CPUs have 20 Gen3 PCIe lanes, with four used for the DMI 3.0 link to the PCH chipset. AMD's AM4 Ryzens have 24 Gen3 lanes, again with four for the chipset—four more are dedicated to the first M.2 NVMe slot. While our graphics cards generally don't need a faster PCIe link, especially with x16 connections, chipsets can run into bottlenecks.

Consider Intel's Z370 chipset, which can support up to 24 PCIe Gen3 links for M.2 slots, USB ports, network connections, audio, and additional PCIe slots. All that data still goes through a tiny straw. Most of the time, we don't hit everything at once, so it's not a problem, but if you try doing RAID 0 with two M.2 SSDs, the chipset link is a limiting factor, and performance isn't much better than the fastest single M.2 drives.

> While graphics cards generally don't need a faster PCIe link, chipsets run into bottlenecks.

M.2 SSDs in general are another area where Gen3 connections are a bottleneck. Many NVMe drives can saturate the interface, topping out at 3.5–3.8GB/s for sequential transfers. With the size of the M.2 connector, going to a wider x8 PCIe link isn't an option—PCIe 4.0 would solve this. USB 3.1 Gen2 is another relatively recent tech, but with 10Gb/s per port, it would only take four ports to saturate the chipset to CPU link.

Graphics cards could also benefit in some workloads—like machine learning and GPGPU. And even though SLI and CrossFire see less use these days, doubling the PCIe speed would mean consumer systems like LGA1151 and AM4 could provide two x8 Gen4 connections that would have the same bandwidth as x16 Gen3.

I wonder if we might skip Gen4 support. There's cost involved in bringing a product through validation and testing, so why test and validate against Gen4, then repeat the process a year later for Gen5? Then again, if we've been OK with Gen3 bandwidth for seven years, doubling it should carry us well into the next decade.

The PCIe x16 slot hasn't changed in appearance much over the years.

We don't necessarily need the extra bandwidth now, but there are scenarios where it could be useful in the future. Leaving it out of current-generation motherboards and chipsets means they're more likely to need an update. It also means we're less likely to see SSDs and graphics cards adopt Gen4.

It's the classic chicken and egg scenario, and for now, PCIe 4.0 is solely used in supercomputers. But I'm hopeful that 2019 will change things, and increase our chipset link bandwidth.

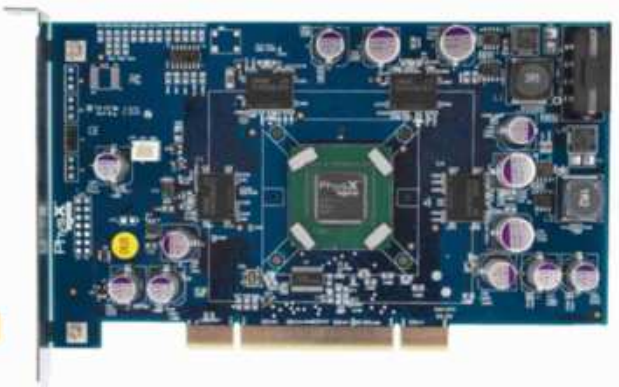
Jarred Walton has been a PC and gaming enthusiast for over 30 years.

THE LIST

TOO SOON: TECH THAT NEVER HAD A CHANCE

8

HD-DVD Toshiba and NEC's modern-day Betamax quickly fell to Sony's Blu-ray, mainly because Sony had the clout to convince studios to release on Blu.



4

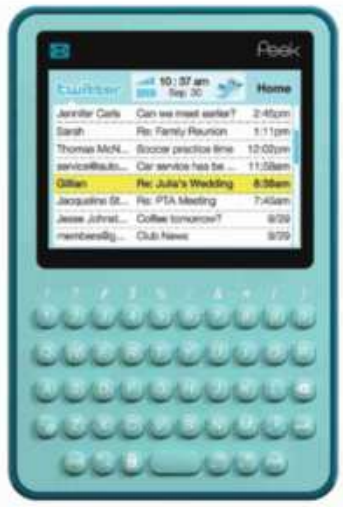
PHYSX It used to need a dedicated card, but poor support, and minimal effect, meant few spent $300.

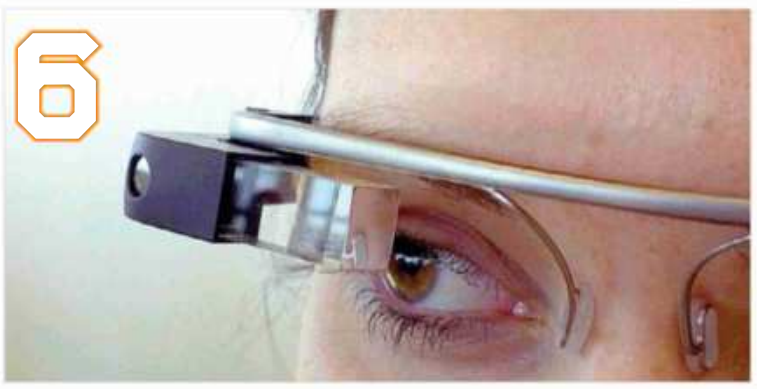
7

WINDOWS XP TABLET PC EDITION In 2002, Bill Gates was excited about this, but input lag, being 10 years early, and a total lack of necessity nailed its coffin.

3

TWITTER PEEK View your tweets on the move in 2009! OK then, view 20 characters of your tweets! That's good enough, isn't it? No? Oh.





6

GOOGLE GLASS Sub-par AR didn't help the $1,500 specs; creepy privacy violations sent them to the trash.

2

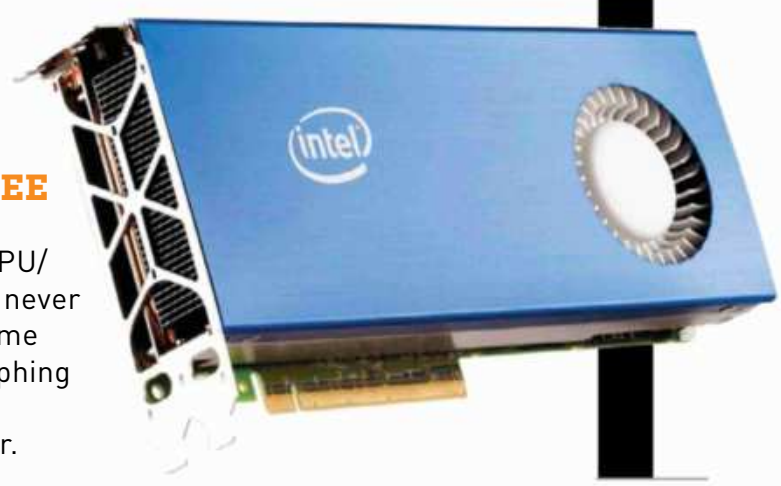
MICROSOFT SPOT WATCH Another case of Redmond firing off too soon, 2004's Spot was a smart-ish watch that pulled its data from MSN, of all places.

5

AMAZON FIRE PHONE Jeff Bezos's best Steve Jobs impression couldn't save Amazon's OS-crippled phone from languid public interest and a freefalling retail price.

1

INTEL LARRABEE Intel's 2009 Larrabee CPU/GPU hybrid never played a game before morphing into the Phi coprocessor.



Alex Campbell

OPEN SOURCE

Linus Torvalds is Taking a Timeout

THE CREATOR OF THE LINUX KERNEL is taking some time off for self-reflection, and is leaving the kernel to the community for now. While this comes as a surprise to those not active in the kernel community, it's hard to disagree with Torvalds on his decision.

This man needs to do some yoga, meditate, or something.

It came as surprise to a lot of people in the Linux world that Linus Torvalds, the Finnish programmer who created the Linux kernel, has announced that he was going to step away from the project. Since he began the venture in 1991, Linux has been the focus of much of Torvalds' professional life. It's no small thing to see him go.

But it's not a bad thing. It's important to remember—as Richard Stallman would remind you—that Linux isn't an operating system; it's a kernel. The GNU operating system is really the core of what we call "Linux." GNU was designed as a free replacement for Unix, but lacked a kernel that would allow the OS to talk to a PC's hardware. Linus Torvalds' Linux project filled that niche, and GNU/Linux was born.

Sure, there is another kernel for GNU, called Hurd, but I've never met anyone who uses it. The fact is that Linux is the most prolific kernel on the planet. The overwhelming majority of servers on the Internet use Linux. The fastest supercomputers use Linux. Android, the most popular mobile operating system by a long shot, uses the Linux kernel. Torvalds created one of the most important pieces of software that powers the modern economy. He is one of the most famous programmers in the world, alongside John Carmack. It's more than enough to influence one's ego.

> Torvalds is one of the most famous programmers in the world. It's more than enough to influence one's ego.

Torvalds has been notoriously rough in his treatment of vendors and code contributors. He famously flipped a bird to Nvidia when talking about the company's drivers. But, more importantly, he has berated code contributors who commit code that is subpar in his eyes. Considering that Linux is an open-source project that still relies on an army of volunteers, this makes him kind of an asshole. Torvalds even admitted so himself. "I am not an emotionally empathetic kind of person and that probably doesn't come as a big surprise to anybody. Least of all me," Torvalds said. "The fact that I then misread people and don't realize (for years) how badly I've judged a situation and contributed to an unprofessional environment is not good."

For many Linux users, Torvalds' behavior has been pretty much invisible. When a user updates the kernel, few bother to read Torvalds' rants on Kernel.org. (Hell, I rarely do.) Most people "apt-get upgrade," and get on with their lives. But for developers, having a code commit merged into Linux is a way to be seen by peers or potential employers. However, to do so, one must be comfortable with the idea of being crapped on over the Internet by one of the most powerful tech leaders in the world.

Yes, coders should have tough skins to be able to take criticism; we writers face it all the time from our editors. But nobody should have to be verbally abused over coding style or pointer errors, let alone in a publicly accessible mailing list for all to see. It would be like an editor screaming at a writer for using "there" instead of "their" on Twitter.

With that perspective, it's good that Torvalds is taking some time to learn people skills. That said, it's good to remember that while Torvalds was head honcho at the Linux kernel project, he wasn't the only one reviewing code. Other people sign off on code commits and merges, so the kernel is still in good hands. And when Torvalds is ready to deal with the fact he works with both code and humans, it will be good to read his release messages on Kernel.org again.

Alex Campbell is a Linux geek who enjoys learning about computer security.

HEAD TO

BY **JEREMY LAIRD**

USB-C vs. HDMI vs. DisplayPort

DVI is pretty much dead. VGA ports are but a distant memory. Welcome to 2018, and the age of the modern digital video connection, where HDMI and DisplayPort rule, the latter in the form of both dedicated DisplayPort sockets and courtesy of an alternate mode via the neat little USB-C connector. But how do these cutting-edge video interfaces compare? Does it matter whether you're gaming or hammering through spreadsheets? Let battle commence.

ROUND 1

Bandwidth

In this age of ever higher resolutions, color depths, dynamic ranges, and refresh rates, the most important metric for any digital display interface is bandwidth. Intriguingly, it's a moving target. Today, 2K displays with 144Hz refresh are becoming more popular. Tomorrow, it will be 4K, then in a few years, 8K and plenty of Hz. This also applies to the interfaces. HDMI first appeared in 2002, and supported up to 3.96Gb/s of raw data, and a maximum resolution of 1920x1200 at 60Hz. Today, the HDMI standard in available devices is at 2.0b spec, delivers 18Gb/s, and maxes out at 3840x2160 at 60Hz. HDMI 2.1 increases that hugely to 48Gb/s, but has yet to appear in shipping devices. The situation with DisplayPort is more complicated. Version 1.4 is the latest spec you'll find, and enables a maximum total bandwidth of 32.4Gb/s. However, by way of example, while Nvidia's GeForce 10 graphics chipsets support DP1.4, it's not implemented in all boards. For some, it can be enabled in a firmware update. Similar uncertainty applies to USB-C, which varies according to the underlying DisplayPort implementation.

Winner:
DisplayPort and USB-C, but check your version

ROUND 2

Features and Ease of Use

We'll drop the suspense on this one, and declare the unambiguous winner: USB-C, of course. It takes everything DisplayPort can do up to version 1.4, and adds a whole slew of funky additional functionality. Firstly, it adds plain old USB data transmission, so you can use a single cable for video signals, and to drive a USB hub on your monitor. It also adds power, and critically in the downstream direction. That means you can use a single cable from a laptop to a monitor to have the former drive the video signal to the latter, and have the latter charge the former. Clever! It's also worth noting that USB-C is entirely reversible. You don't have to fumble around the back of a PC or display trying to orient the end of the cable correctly. It works both ways. As for the contest between DisplayPort and HDMI, it's probably a dead heat. Both support audio and video simultaneously. HDMI has the edge in terms of commonality—it's the interface of choice for consumer video products—while DisplayPort takes the prize for flexibility, thanks to its support for daisychaining multiple displays from a single output source socket (something USB-C also offers).

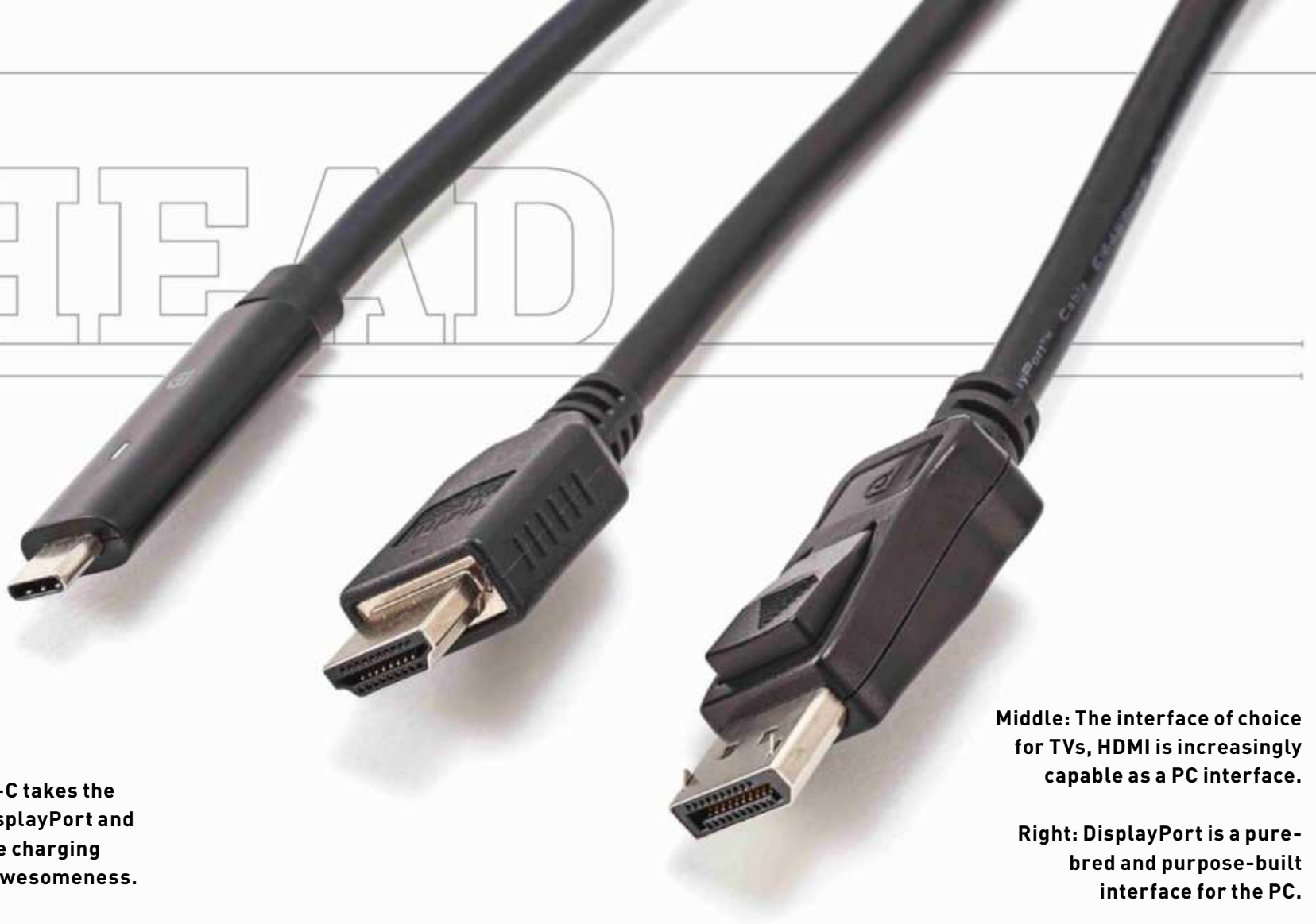
Winner:
USB-C, easily

ROUND 3

Gaming

So, you game a lot. But does it matter what video connection interface you use? That depends, mostly, on your display. If you have a pretty basic monitor with 60Hz refresh, modest native resolution, and nothing by way of features such as adaptive sync, it makes little difference. If you want to drive a VR headset with a single cable for power, video, audio, and control input, there's only one option: USB-C. In the middle, DisplayPort tends to be the best option for gamers, because of the greater bandwidth from DisplayPort 1.4. If you have, for instance, a 1440p monitor at 144Hz, both HDMI 2.0 and DisplayPort 1.4 have you covered. Up to 4K and 144Hz, however, only DisplayPort 1.4 will get the job done. Then there's adaptive sync and variable refresh rates. That includes Nvidia's G-Sync tech and AMD's simpler FreeSync. For now, DisplayPort is required to access these features, and thus improve the smoothness of your gaming, even at lower frame rates, while eliminating screen tearing. However, the upcoming HDMI 2.1 includes support for the VESA variable refresh rate standard.

Winner:
USB-C for VR, DisplayPort is OK for everything else



Left: USB-C takes the best of DisplayPort and adds some charging and USB awesomeness.

Middle: The interface of choice for TVs, HDMI is increasingly capable as a PC interface.

Right: DisplayPort is a pure-bred and purpose-built interface for the PC.

ROUND 4

Productivity

Getting things done makes different demands on your PC from gaming. So, what's best for content creation, work, and generally making things happen? In part, that depends on your budget. Larger screens with higher resolutions and greater dynamic range require more bandwidth, for instance. Right now, anything beyond 4K remains pretty niche. On the other hand, future-proofing is worthwhile, even if you can't afford the latest $3,000 8K display. If you're buying a new PC, something with a graphics subsystem that supports 5K-plus is worthwhile. After all, 4K monitors went from exotic to fairly affordable in just a few years. The same will probably happen with 8K within five years. Today, that means DisplayPort or USB-C, but with the caveat that you need to check what version of DisplayPort is supported in each case. DP1.4 is what you want to ensure support for future high-res displays. Of the two, USB-C has the edge. It gives the full DisplayPort experience, and adds USB functionality, plus the ability to charge and drive a display, all with a single cable. That's a major benefit when it comes to keeping work areas tidy.

Winner:
USB-C

ROUND 5

HDR

High dynamic range, or HDR, is the latest and hottest display tech. It also makes very particular demands of your display subsystem. The HDR10 standard includes 10-bit per channel color, so requires 25 percent more bandwidth than conventional 8-bit color. HDMI 2.0b does support HDR, but only up to 4K and 50Hz. For 4K at 60Hz over HDMI 2.0b, the chroma subsampling must be reduced slightly to reduce the bandwidth, which means you're not getting the full range of colors. HDMI 2.1 will deliver the full HDR10 experience at 4K and 144Hz, or higher resolutions with lower refresh rates, but HDMI 2.1 devices aren't quite here yet. As for DisplayPort (and USB-C), HDR support was added with version 1.4. That supports HDR at 8K and 60Hz using "visually lossless" Display Stream Compression, or HDR at 4K and 60Hz without any compression or chroma subsample reduction. So, as it stands, the current best DisplayPort implementation is superior to HDMI for HDR. The catch is that no new DisplayPort standard has been announced, while HDMI 2.1 will outstrip DisplayPort 1.4.

Winner:
DisplayPort and USB-C now, HDMI later this year

And the Winner Is...

The overall winner among today's display standards for the PC is clear. It's USB-C. It's the most flexible, feature-rich, and capable of the three main options. The ability to plug a laptop into a monitor with a single cable, and drive it at very high resolutions and refresh rates, at the same time as charging the laptop and enabling the connection of USB devices is very, very cool. USB-C is also perfect for next-gen VR gaming with a single cable. Even on the desktop, the simplicity implied by USB-C is a significant boon. Of course, remember that USB-C as a display connector is only as good as the DisplayPort interface underneath. Also bear in mind that this subject is something of a moving target. HDMI 2.1 has been announced, and should soon begin to appear in devices. It has the edge on DisplayPort 1.4, and thus USB-C, for outright bandwidth, if not overall features, so may be the better option for some edge cases with really high spec displays. Meanwhile, the upgrade path for DisplayPort, and its support for future cutting-edge PC monitors, is a little uncertain.

DOCTOR

THIS MONTH THE DOCTOR TACKLES...

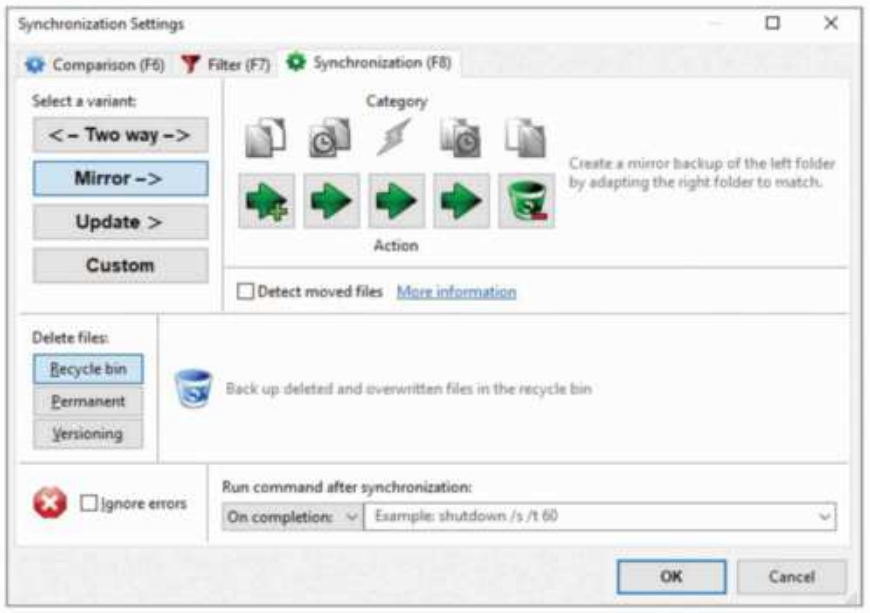
> Version Control
> Secure Systems
> Upgrading Graphics

File Versioning

In the August 2018 issue, your response to Mr. Monarrez on a Time Machine alternative caught my interest. I lost a version of a file because I modified it twice between backups. I don't use File History because it only looks in certain folders, but I have a financial program called Quicken with a neat option that lets you add a date stamp to the file name every time it's backed up.

The other programs you mentioned seemed to be backup-oriented. However, I'm looking for a utility that sits in the background and only backs up the files I select whenever they're saved to disk (preferably with a date stamp). I know there are programs like this in the coding world (version control), but I haven't found anything that satisfies my requirements for Windows.

–Derek Hamilton



FreeFileSync supports file versioning, enabling you to roll back .

THE DOCTOR RESPONDS:
Don't give up on File History. Go to the Windows Settings home screen, click "Update & Security," then choose "Backup." Under "Back up using File History," click the "More options" link. "Back up these folders" does give you control over the locations that Windows monitors for changes. By default, the OS saves those files every hour, and keeps backups indefinitely, but you can force Windows to check for updates every 10 minutes.

Alternatively, there's an open-source synchronization tool called FreeFileSync that maintains multiple versions of old files with added date stamps. Beyond the software's backup capabilities, you can open its synchronization settings, change the "Deleted files" option to "Versioning," and choose a naming convention. "Replace," "Time stamp [File]," and "Time stamp [Folder]" all affect the utility's behavior in ways that suit various organizational styles.

Building a Secure PC

Hi Doc! As the saying goes, I'm a long-time reader and first-time caller, hoping you can help with a question on addressing the Meltdown/Spectre chip issues.

A few years back (alright, it was 2014), I took great pride in following one of your PC building guides. I ended up with an Asus Sabertooth X79 motherboard, Intel Core i7-4820K CPU, GeForce GTX 760 graphics card, Samsung 840 EVO SSD for my OS, and a Seagate 3TB hard drive for my personal files. I installed Windows 8.1 but claimed the free upgrade to Windows 10 when it became available.

I did some reading about the Meltdown/Spectre issues, and it looks like Intel published microcode to mitigate my CPU's vulnerabilities. However, Asus hasn't updated the Sabertooth X79's BIOS to apply it. Given that the last firmware was released several years ago, I don't think it's going to happen.

I'm considering a motherboard and CPU upgrade (probably DDR4 memory as well). At this point, I might as well spring for an entirely new build, including fresh installations of Windows and Office. But that seems like a lot of faff. I was really hoping to just yank the board, processor, and RAM, replacing them with everything else intact. My wife uses the PC often, so I want the result to be transparent for her. Same drives, same programs, same look and feel, etc.

Can you offer any suggestions? I can't be the only "mature" PC novice with an aging build facing security

↘ submit your questions to: doctor@maximumpc.com

concerns due to unsupported components. Thanks, and keep up the good work!

–Adam Colley

THE DOCTOR RESPONDS: Don't feel pressured to replace your platform if you'd rather not mess with its configuration, Adam. Microsoft offers a software patch for Windows 10 that injects microcode to stymie Spectre Variant 2 attacks. The patch should roll out automatically via Windows Update, but use the InSpectre tool (www.grc.com/inspectre.htm) to make sure you're protected. If the utility says you're not, visit Microsoft's Update Catalog (www.catalog.update.microsoft.com) and install KB4100347.

Since older CPUs, like your Core i7-4820K, do incur a more significant performance hit post-patch compared to Intel's newer processors, an upgrade may still be timely. As suspected, you'll need a CPU, motherboard, and memory kit at the very least. But before you start dropping Core i9s or Threadrippers into an online shopping cart, remember that silicon with baked-in fixes for those security issues is due.

The Doc suggests securing your system as it sits, waiting a while longer, then taking the leap once hardware-based mitigations close the door on documented vulnerabilities.

Growing a RAID Array

Doc, I have a Plex server running in RAID 1 with three 4TB enterprise-class disks, giving me a total of 8TB for storage. I still have 2.5TB available but am envisioning a time when I'll need more. I asked my computer guy, and he does not know the answer to this question: If I want to swap in 6TB hard drives, is there a way to do this without starting from scratch? The OS and programs are on a 500GB SSD. **–Bruce S. Bevitz**

THE DOCTOR RESPONDS: It should be possible to swap in one drive at a time, rebuilding the mirrored set after each new disk is installed, until you can expand the pool. Or, if you have enough SATA ports, create an array with the 6TB drives, and copy your media over from the 4TB disks.

Adios, Legacy Support

Hello Doc, Over a year ago, I noticed that HP was removing support pages for older systems from its website. Drivers and specs disappeared. More recently, I had an issue tracking down information on a 2011-era Lenovo IdeaPad Z560 model 0914. Just because a computer is seven years old, doesn't mean it can't still be used for word processing and email. Luckily, most drivers were installed by Windows 7. I did have to search Google for a Wi-Fi driver, which was still listed elsewhere on Lenovo's site.

During my search for more updates, I found a beautiful page on Intel's site that detects hardware devices and available drivers (http://downloadcenter.intel.com). It provides details on your processor and chipset, how much RAM you have, hard drive information, and more. I looked to see if AMD has something similar. Its website has a link to a utility that is supposed to autodetect hardware, but it looks like that page is down, because it points to a support page for manually choosing what you need to download.

It's a pity that tier-one manufacturers are removing support pages for older systems. **–Leon Garfield**

THE DOCTOR RESPONDS: AMD's autodetect tool is dissimilar from Intel's in that it was only meant to look for desktop graphics hardware and Windows versions. If the utility determined a newer driver was available, it would help with the download. This functionality is no longer needed; you can check for updates through AMD's Radeon Settings interface (right-click the desktop and select "AMD Radeon Settings," or click the Radeon Settings icon in the system tray).

The GeForce RTX 2070 offers fast frame rates and modern features, starting at $500.

Upgrade or Replace?

Hey Doc. I've been on the fence about whether to upgrade or replace my PC. I have an Alienware Aurora R4. It has a Core i7-4820K overclocked to 4.1GHz, 16GB of DDR3 RAM, a 500GB Samsung 850 EVO SSD as the boot drive, a 2TB data drive, and a GeForce GTX 780.

I was thinking about replacing the graphics card with a GeForce GTX 1080, though I believe I'm limited to boards with one eight-pin power connector, due to my PSU. Thanks to the cryptocurrency crash, prices on graphics cards are still coming down. My existing configuration still runs games at decent-looking quality settings (mid to high), but has a hard time utilizing my 144Hz monitor at more demanding detail presets.

One perk of a new system would be that I'd build it, rather than buying a pre-configured PC. What do you recommend? **–Jack Morphy**

THE DOCTOR RESPONDS: Intel's Core i7-4820K is more than five years old, but its Ivy Bridge-E architecture, four Hyper-Threaded cores, and 10MB of L3 cache are still capable of high-end gaming. Most of your other specs seem ample as well. However, that GeForce GTX 780 is a bottleneck, especially if you're trying to play fast-paced shooters at 2560x1440 on a 144Hz display. Upgrading to a GeForce GTX 1080 (or even an RTX 2070—both require a single eight-pin power connector) would have a huge impact on frame rates without the cost of a completely new PC. And when you do finally build an updated system, simply move the graphics card over to its new home.

Laptop Graphics

I have a Dell Inspiron 15-5559 laptop with Windows 10 Pro. It plays host to 8GB of memory, a 256GB SSD, and built-in graphics (from Intel, I believe). Is there any way to improve video performance? I've read that it's possible to build or buy an external contraption.... **–Stu Parker**

THE DOCTOR RESPONDS: According to Dell's spec sheet, the Inspiron 15-5559 was available with Intel sixth-gen Core i3, i5, and i7 CPUs. That means it included HD Graphics 510 (with 12 execution units) or HD Graphics 520 (with 24). Either way, performance was anemic at best. Dell also lists an AMD Radeon R5 M335 discrete option, but it wouldn't have been much faster.

Higher-end graphics wasn't in the cards for Dell's Inspiron 15-5559. Pictures from the service manual show AMD's GPU soldered to the mainboard. You can't pull it out and drop in something better-suited to gaming. Moreover, a lack of high-speed I/O means there's no way to connect an external graphics enclosure (the contraption you referred to). Most turnkey products use Thunderbolt 3, while some homegrown solutions hook up via an ExpressCard slot. The Inspiron has neither; its fastest interface is USB 3.0.

UPGRADES

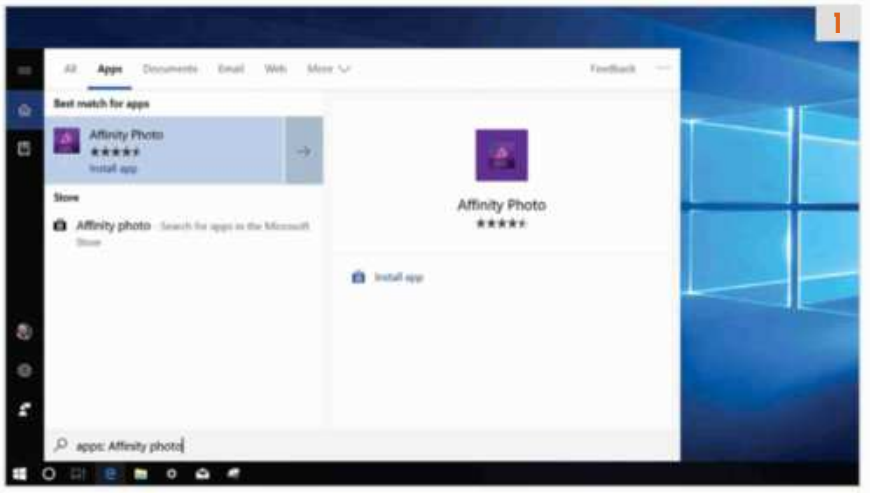
BY **IAN EVENDEN**

Major Features from the Latest Windows Update

The Windows 10 October 2018 Update—because Microsoft loves simple names—is due soon, and may already be downloading by the time you read this. It's the sixth major release for Windows 10 since it first hit in July 2015, and it arrives through Windows Update. It's not necessarily a bad thing—although it might be nice if Microsoft let us just get on with using our PCs—but this release seems a bit light on actual new features. We spent some time with the Insider Preview to see what's actually new.

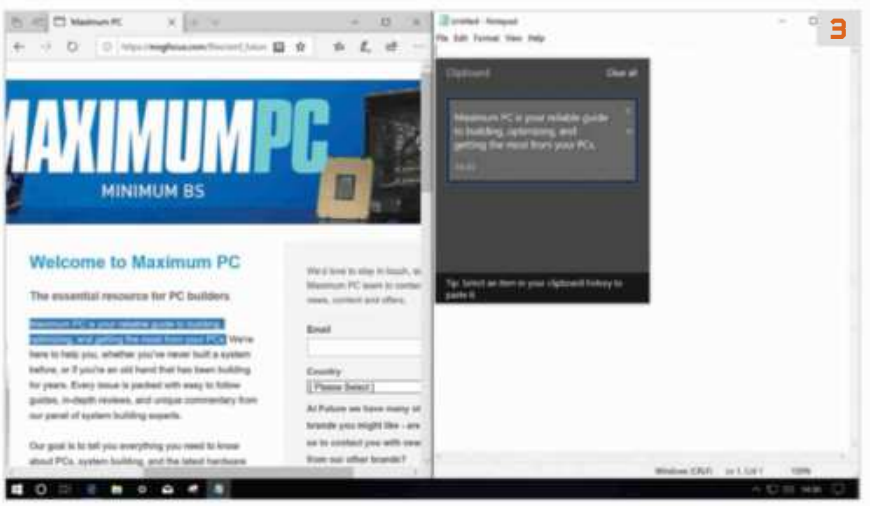
1 Start Menu and Searching

You can now name tile folders on the Start menu, and hide the scrollbars using an option in Ease of Access, but the biggest change is in searching. It's got a wider interface, and if you search for an app that's not installed, you get an install link under the "Apps" header. Bing searches also launch straight out of the Start menu in Edge, but the promised nagging to get you to change from Chrome or Firefox to Edge seems to have been forgotten about.



2 Cosmetic Changes

Lovers of the dark side can find a choice of "default app modes" in "Settings → Personalization → Colors." There's only "Light" and "Dark," so it's not a huge decision, but the difference between them is enormous. Elsewhere, Action Center has new animations, and users of the Snipping Tool (mainly people who make lists for magazines) should note it's being phased out in favor of a "Screen Snip" option on the Action Center and a Snip and Sketch app. Hopefully, this'll fix Snipping Tool's problem with catching itself in its own screenshots.



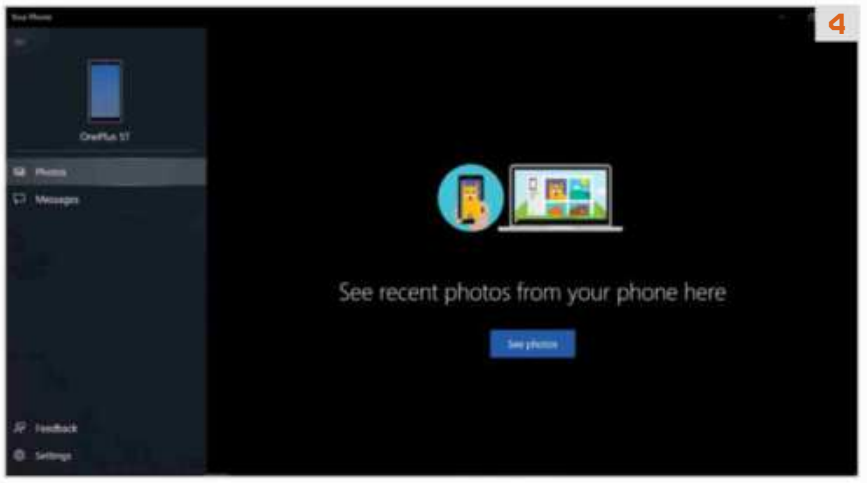
3 Clipboard

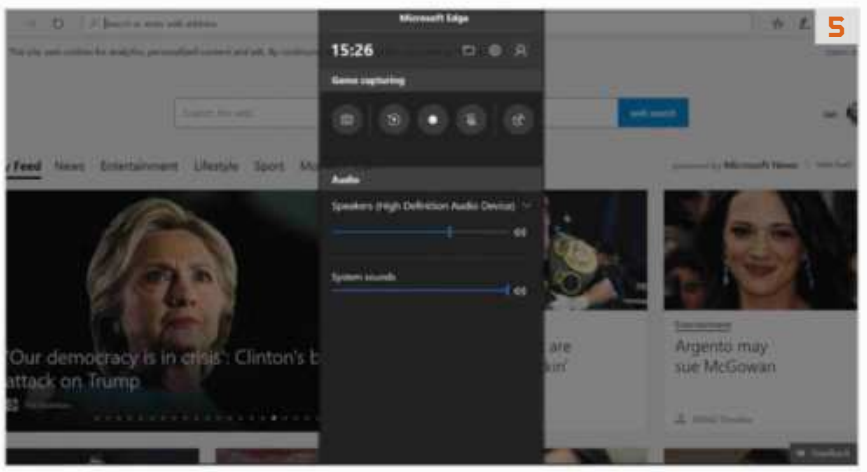
Copying and pasting isn't exactly the most exciting feature, but it's good to see such an old Windows stalwart getting a makeover. In addition to the old Ctrl-V to paste, there's now a Windows-V option that needs to be activated the first time you use it. After this, everything you Ctrl-C is remembered, not just the last thing, and you can choose what to paste from a list when you press Windows-V. There's also an option to clear the list. It gets better, because if you're logged into Windows 10 using the same account on multiple devices, this clipboard history is shared through the magic of the Internet. As long as it's just snippets of text, that is—there's no ability to sync copied pictures as yet. There are, of course, various settings to control this behavior in the new "Clipboard" section of Settings.

A future goal is the addition of Cloud Clipboard synching to the Swiftkey keyboard for mobile devices, purchased by Microsoft in 2016, which would make a lot of sense. The keyboard has come to Windows, too—the on-screen keyboard is "powered" by Swiftkey.

4 Phone Connectivity

There's a "Your Phone" shortcut prominently placed





at the top-left of a desktop that's clear of other icons apart from the Recycle Bin. Double-clicking this opens a window that asks for your cell phone number, and sends you a link to an app on Google Play (so it's Android-only for now; an iOS version is coming) for Your Phone Companion. This is a rebrand of the old Microsoft Apps, and still contains links to download mobile versions of Outlook, Solitaire Collection, and Edge, but it now links to the Your Phone app on Windows, as long as you're signed into the same Microsoft account on both.

Once they're linked—you need to give permission—Your Phone can view the photos (if you give permission) and read the SMS messages (again, permission needed), and it must read your contacts, too, as the correct names appear next to the messages. The photos are described as "recent"—for us, it displayed only the past three days' worth—and while there's no explicit "Save" option (a double-click opens them in the app of your choice), you can drag them from Your Phone on to the desktop. Text can be copied from SMS messages, and you can write new messages, too, with contacts autocompleting in the "To" field. SMS may be old-fashioned in these days of Skype and WhatsApp, but it's clever, nonetheless.

5 Game Bar

Windows 10 taught us that anything can be a game as far as the Game Bar is concerned, so you can capture video of any app, and the updated version is no different. It no longer asks you up front if the app you want to capture is a game, and we're quite pleased about that, as it was just a little silly. It's not really a bar any longer, more of a column, and it enables you to capture screenshots and video from inside any app.

6 Windows HD Color

If you've got a fancy new HDR monitor, there is now a section in Settings dedicated to the display of High Dynamic Range and Wide Color Gamut content. It's rather limited, though, telling you whether your screen is capable of displaying the content to its fullest, and linking to video playback settings.

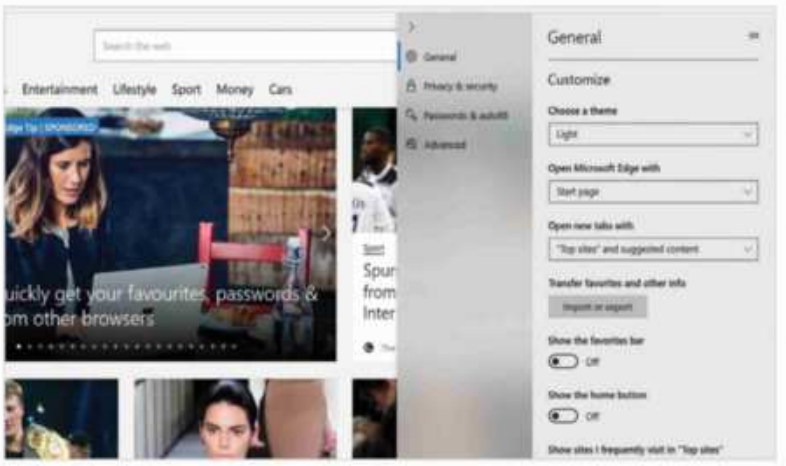
7 Other Changes to Settings

Bluetooth devices now display their battery levels in Settings, and there's a new section in Typing, called Typing Insights, that claims Windows is using AI to help us type. Windows has clearly never seen our unedited typing, otherwise it wouldn't offer, but by clicking "Typing Insights," you get a rundown of how many times the AI has corrected your typos and autocompleted words, assuming you have autocorrect turned on.

There's also some under-the-hood stuff, such as safely removing external GPUs connected by Thunderbolt 3, a new column in Task Manager that shows how much energy various processes are using, and Photos can now rotate images taken in HEIF format (this will mainly be of interest to those sporting top-end iPhones). Pen users will now find handwriting recognition is the default input method, too.

[HIGHLIGHT]

EDGE



Microsoft's campaign to get millions of Chrome and Firefox users to switch to Edge continues, but there aren't many new features—things like the redesign of the three-dot menu that now groups icons, and a new look for its settings page. There are controls for autoplaying media, including blocking them, but you can also manage them on a per-site basis, and you can turn off Flash content.

Edge tabs now appear in the Alt-Tab task switcher, and your most commonly visited sites appear in a Jump List when you right-click the Edge icon on the Taskbar. There's now dictionary lookup if you highlight a word in the PDF viewer or in Reading View, and there are new page color themes for the latter, while the former gets an "Add Notes" option on its toolbar, which can now also be pinned open.

A lot of the cosmetic changes are down to Edge taking on Microsoft's Fluent Design philosophy, which is meant to be the future of Windows in the same way Aero was a while ago. This means shadow effects and content layering to give apps depth, an emphasis on color, animation, and standardization of UI sizes, so things aren't too big for mouse users or too small for touchscreen fiddlers. Fluent Design is also making its way to Xbox One, with an overhaul of the interface, and should lead to prettier apps now that most PCs have the horsepower to display them.

$285 BUDGET-BUSTING BUILD

Combining modern hardware with a tight budget, how low can you go?

What would life be without a little challenge along the way, eh? Whatever your passion or your hobby, finding new ways of testing yourself, and pushing the limits of what you can do, is key to achieving fulfillment for us human beings. Whether that's in sport, in gaming, with PCs, or in your work, there's no arguing that it's part of the human condition, and something we're all secretly obsessed with.

The reality is, we're masochists. All torturing ourselves to become better at what we do, constantly striving for more. At least, we are here in the office. Not literal masochists, of course, although that's not to say there's anything wrong with that. Far be it from little ol' *Maximum PC* to tell you how to conduct your love life. It's more to do with the fact that we just love pushing the boat out as far as it'll go. Whether that's expanding our technical knowledge, building even crazier high-end systems, or getting the absolute maximum out of a budget part, it all helps to enhance our experience as journalists, and bring you better content and coverage in turn.

Wait, where were we? Oh yes, of course: system building. So, that big cheese from the front of the mag, or "el editor de la muerte," as we like to call him in the office, set us a challenge. With the launch of AMD's latest Athlon processor (an anniversary edition, which is secretly a super-cheap Ryzen part with integrated graphics), he wanted to see just how little we could spend on a relatively fast rig that would be capable of doing light PC work. We say "wanted," but he essentially delegated this to the smaller cheese, and here we are.

The rules were simple: Spend no more than $300, use a single stick of DDR4 (again, masochism, right?), and install Linux. Oh, and try to get it playing a game of some description.

So, join us on a journey into the wonderful world of super-budget builds, as we struggle with BIOS updates, argue over finding the perfect parts, and pull out what little hair we have left between us while we benchmark it to hell and back. *–ZAK STOREY*

INGREDIENTS		STREET PRICE
Case	Raijintek Arcadia	$46
Motherboard	Asus Prime B350-Plus	$85
CPU	AMD Athlon 200GE	$55
Memory	4GB (1x 4GB) Crucial Ballistix Sport LT DDR4 2400	$42
PSU	EVGA BT 450W 80+ Bronze ATX	$29
Storage	120GB Crucial BX500 2.5-inch SSD	$28
Cooling	Stock	$0
Operating System	Linux	$0
Total		$285

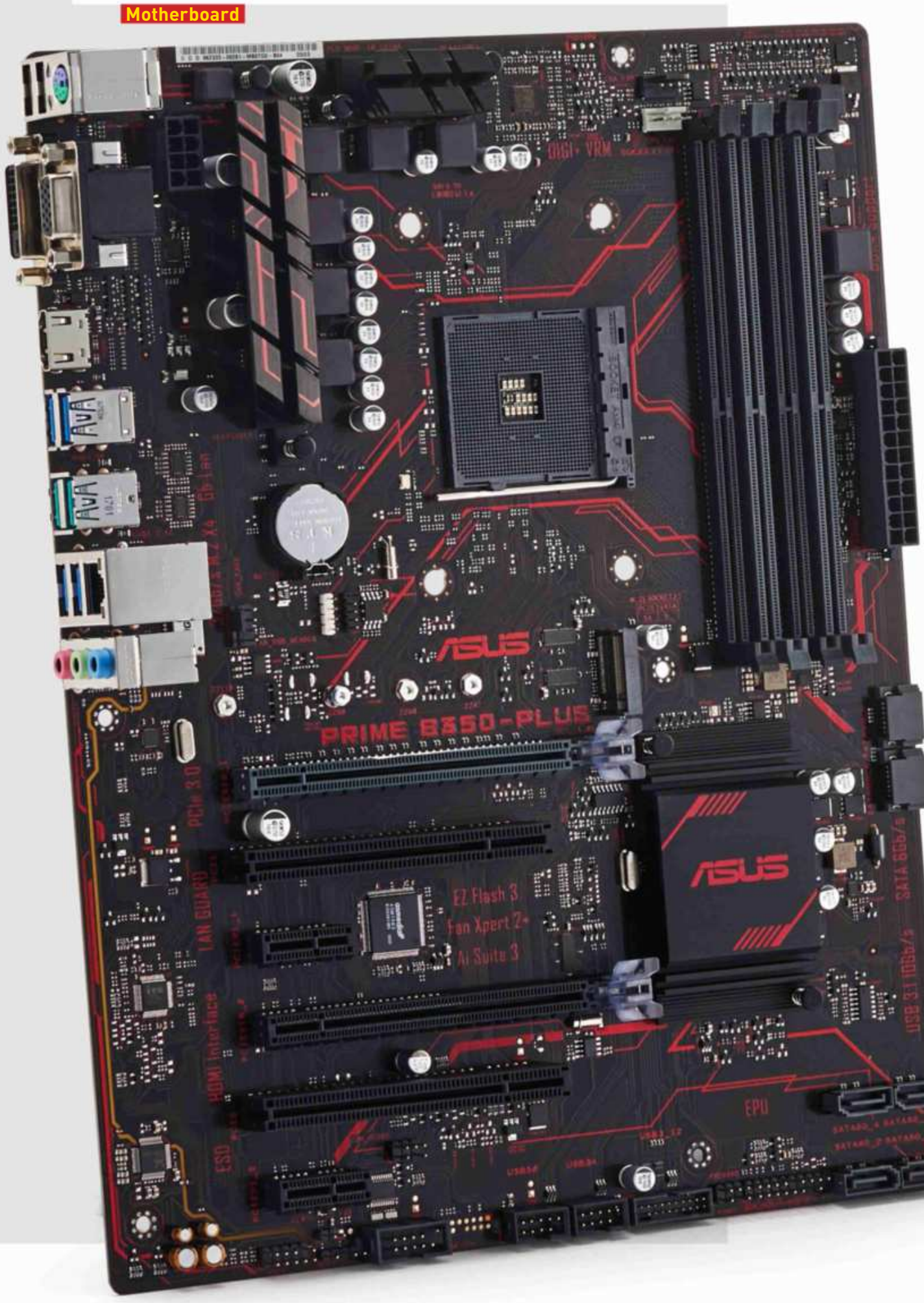
BUILD IT! P33

$85 \ ASUS PRIME B350-PLUS

One of our favorite budget motherboards of late, Asus's B350-Plus is a nice compromise between price and feature set. This packed ATX board has support for M.2, six SATA 6Gb/s hard drives, and even multiple GPUs (although, you should bear in mind that the Athlon we're using won't support more than one). On top of that, it's bursting with a plethora of rear I/O, from eight USB ports to Ethernet-out, 3.1 audio, DVI-I, VGA, HDMI, and even an old-school PS/2 combi port.

You could effectively save more money here if you're thinking of doing your own build by opting for a microATX board instead (in fact, Gigabyte does the GA-AB350M-DS3H, with HDMI and Ethernet, for less than $50 currently). However, our OCD desire to get a reasonable ATX motherboard to fit inside our ATX case won over in the end.

Motherboard

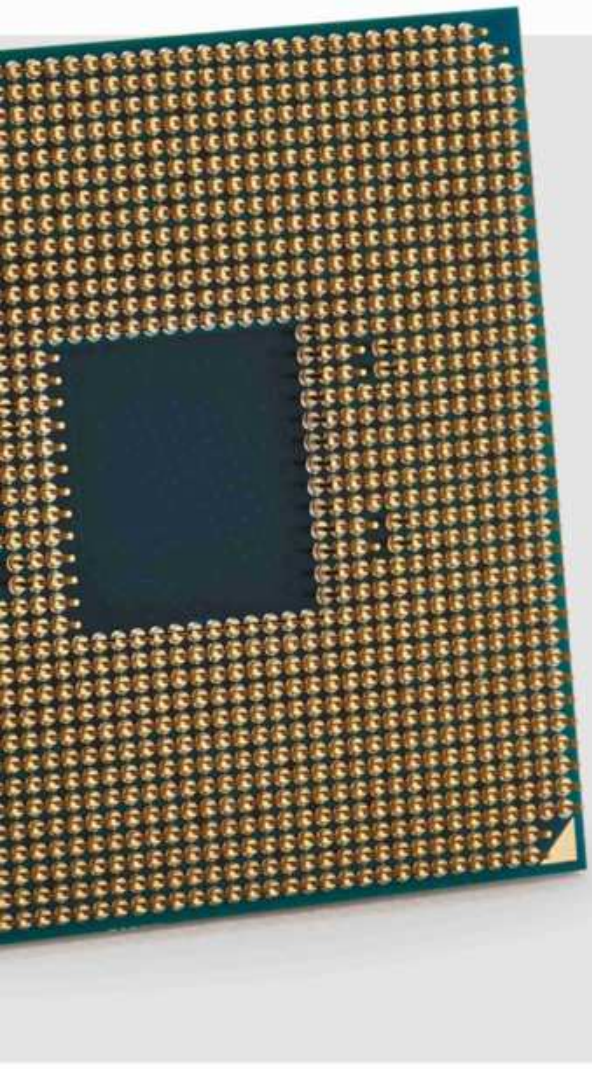


BUILD IT! P33

$55\AMD ATHLON 200GE

AMD's legendary Athlon CPU first arrived in 1999. Built from the ground up to take advantage of a copper interconnect, it was the first AMD part capable of hitting that 180nm sweet spot at 1GHz. Fast-forward almost 20 years, and we're witness to AMD's revival of the brand, in a very different package.

In short, the 200GE is a two-core, four-thread Ryzen processor with integrated graphics, featuring three Vega cores (the Ryzen 3 2200G has eight for $100, and the Ryzen 5 2400G has 11 at $160), and support for all of AMD's latest chipsets. It comes with DDR4 support at 2,666MT/s, a super-low TDP of 35W, and even a cooler (annoyingly, ours was an engineering sample). The big selling point, however, is the price; $55 makes it ideal for any home theater PC, light office machine, or super-budget esports (or MOBA) gaming rig.



CPU

$42\CRUCIAL BALLISTIX SPORT LT 4GB (1X 4GB) DDR4 2400

Here's that one stick of memory we were talking about earlier. One stick of glorious single-channel perfection. This 4GB stick should be enough for any light office work, once again. There's not a lot to it: It's red, so that's a plus, as it goes nicely with the motherboard. Not that you'll see either, because the case doesn't have a windowed side panel.

However, getting a dual-channel kit at 8GB instead should only set you back $82, and it's a setup we'd recommend if you plan to do anything more taxing with your system later on. Google Chrome, although better than it once was, is still a memory-killer—with five tabs open and a few extensions, you'll likely be using 1.8GB or so. Pretty crazy, huh? Combining that with the $50 Gigabyte board we mentioned opposite should net you a system with a far better spec for about the same price.

Memory

BUILD IT! P33

Storage

$28\120GB CRUCIAL BX500 2.5-INCH SSD

No traditional hard drives here. No, sir. This time around, we've gone for a 120GB budget SSD from Crucial. These new BX500 drives are aimed solely at the entry-level market. Surprisingly, despite the price point, they're actually fairly impressive on a spec level. With 540MB/s read and 500MB/s write, it's aggressively competitive, particularly at that price.

It's worth bearing in mind again, however, that although this drive is enough for your Windows installation and some light program use, if you intend to install any sizable games later down the line, or decide that you'd like to use this machine as a home theater PC, we recommend you pump out for a more substantial old-school HDD—something like a 1TB WD Blue, for example. Better yet, cannibalize one from an older system.

Power Supply

$29\EVGA BT 450W 80+ BRONZE ATX PSU

Another budget build, and another delve into the realm of EVGA's super-budget BT450 power supply. Yup, this is one of those kind of builds. It's hard to recommend anything else when it comes to super-low-end power supplies. We always suggest that you go with a known brand, because it provides you with a bit more peace of mind, and if things ever go wrong (and they can and do), you can rest assured that there's some form of warranty behind you. And, let's face it, EVGA's warranties have become legendary.

That said, is a 450W power supply enough? The answer: Yup. From the wall, we're expecting this rig to draw around 50W total peak power, or within that area. You could throw in a GeForce GTX 1080 Ti 11GB (seriously, though, don't do this), and still be left with 150W of headroom to play with. So, there's plenty of room for expansion later down the line if you want to swap out that GPU, CPU, or memory.

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$46 \ RAIJINTEK ARCADIA

When Raijintek offered us this case for our budget endeavors, we were pleasantly surprised by the quality of the interior. As technology journalists, when we get a case that costs less than $50, we never really expect much from it—whether it's the build materials, interior features, or whatever, you're usually short-changed with a budget case. To say they're underwhelming would be an understatement.

Raijintek's Arcadia, however, ain't half bad. The interior's roomy, there's a ton of included accessories, support for 2.5-inch drives and 3.5-inch toolless drives, acceptable cooling support, and even room in the back for some cable management. You could even fit a 240mm AIO in the roof if you wanted.

Case

IT'S TIME TO BUILD OUR BUDGET-BUSTER

DESPITE WHAT YOU MIGHT THINK, speccing out a budget build like this is never easy. In fact, more often than not, not only are the components more difficult to source than their many-thousand-dollars-more counterparts (companies tend to be really reluctant to lend us budget hardware), but making sure that each dollar that we do spend is well accounted for is far more challenging at the lower end of the system-building spectrum than at the mid to high end. Price to performance is the metric of choice here, and everything—and we mean absolutely everything—is about keeping that metric balanced when picking the parts that matter.

Even then, there are exceptions, so let's talk about some example scenarios. Say this is the only rig you'll be using for the next 10 years. You'll want to spend around 30 percent of your budget on the processor, 20 percent on storage, 20 percent on memory, and the final 30 percent on everything else. However, if you're planning on it being a stop-gap rig—that is, you're going to be upgrading the CPU at a later date—it might be wiser to drop more cash on the motherboard, memory, and storage, and get a super-budget CPU at this point to keep you going until you upgrade.

That said, it's about time we covered the rules for this build. First up, there's the budget, a nice stress-inducing $300 to play with (management does love putting a big number on the cover), then we're limited to one stick of DDR4, to see how it affected performance at this level of computational use, and finally we had no choice but to use AMD's latest Athlon (by name but not by nature) 200GE processor, because it's really cheap, and a competitor for Intel's Pentium lineup. Everything else was up to us.

INGREDIENTS

PART		PRICE
Case	**Raijintek Arcadia**	**$46**
Motherboard	**Asus Prime B350-Plus**	**$85**
CPU	**AMD Athlon 200GE**	**$55**
Memory	**4GB** (1x 4GB) **Crucial Ballistix Sport LT DDR4 2400**	**$42**
PSU	**EVGA BT 450W 80+ Bronze ATX**	**$29**
Storage	**120GB Crucial BX500 2.5-inch SSD**	**$28**
Cooling	**Stock**	**$0**
Operating System	**Linux**	**$0**
Total		**$285**

PRICES WERE CORRECT AT TIME OF PRINTING.

1 PRE-BUILD PREP

ALL GOOD PC BUILDING STARTS with preparing your work area. You'll need a couple of Phillips screwdrivers, maybe a pair of scissors for cable ties, and that's about it. A magnetic screwdriver is useful, in case you drop any screws, and a bowl to hold them in is also a good call. Static isn't a huge deal nowadays—just make sure you're grounded before you start, by touching something metal that's not a component. Once done, take your case, and give it a full strip-down. Remove every panel you can to make things as easy as possible when inserting hardware. This is also a good time to take your hardware out of the boxes for inspection. Remember: Anti-static bags are conductive on the outside, and can retain charge, so never place any hardware on top of them.

2 REAR I/O

SO, YOUR CASE IS STRIPPED of everything, the hardware is unboxed, what's next? Rear I/O shield, always the rear I/O shield. Pop this bad boy into position by aligning it with the ports on your motherboard, and pushing it from the inside of the case. It'll click into position. On cheaper ones, you might need to bend the pins to make sure your motherboard can fit into position afterward, because they're notorious for getting stuck in ports, and generally being in the way. On more expensive motherboard options, the rear I/O shield is generally padded, and more of a premium affair—it's only at the absolute budget end of the spectrum that you'll encounter them like this. Some even come pre-attached.

3 POWER SUPPLY

WE'RE GOING TO DO THINGS differently, and install the PSU first. There are only a few parts that need to be installed in a strict order, and this is usually to do with clearances or logic. For instance, CPU before cooler, fans after mobo, and so on. When it comes to your PSU, it can vary. For a case with good cable management routing, you can leave it till last. For us, getting it in early lets us figure out where we're going to route our cables, particularly the troublesome CPU power at the top of the board. In the Arcadia, there's no top cutout for the CPU; usually, we'd be cheeky, and run it under the motherboard, and pop it out of the top, but that wasn't possible. Instead, we've run it out the back of the motherboard tray, up through the top, then along the top edge. It's not the tidiest solution, nor the easiest, but it's the best option we have.

4 MOTHERBOARD INSTALLATION

NEXT UP IS the motherboard. By default, your case should come with the stand-offs pre-installed. If they're not, look inside the box of bits and pieces that comes with your case. Then, depending on the size of your motherboard, locate the correct mounting holes in the chassis. These will be labeled "M" for microATX, "A" for ATX, or "I" for ITX. Some holes are the same across all three types of board. Line the stand-offs up with the holes on your motherboard, and screw them into place. Some cases (Cooler Master in particular), come with an adapter you can add to a Phillips screwdriver to secure them in place, or you could needle-nose pliers, after tightening by hand. Then line the motherboard up with the rear I/O shield and the stand-offs, and secure it with the correct screws.

5 PROCESSOR AND CABLE TIME

NOW IT'S TIME TO INSTALL that pretty little Athlon processor of ours. To do this, move out the little lever to the side of the CPU socket slightly, and lift it up. Then, line up the gold triangle on the corner of the processor with the triangle cutout on the socket, and gently drop your processor into place. Give it a little wiggle to make sure it's seated securely, before pushing the retention arm back down into position. You'll also notice that we've installed our power supply cables here, too, with both the ATX 24-pin and the CPU pin running through the back of the case, and through that top cable cut-out to the right of the board. Don't worry about installing the wrong cable in the wrong hole—it's physically impossible to do so, because each pin has a specific square or pentagonal plastic housing to prevent you from doing so. Just remember to plug them in, and make sure the CPU or EPS power goes into the CPU connector.

6 MEMORY MISCHIEF

NOW WE COME to the crux of this whole experiment—the single stick of RAM. Yup, just one stick of memory, in all its single-channel glory, will be powering this budget-busting build. When it comes to installing DDR4, there's not a lot to it. Simply lift the pin on the slot you want to install the memory into, match up the notch on the motherboard with the notch on the stick of RAM, then carefully push the memory into place, until it clicks down securely, and the latch tucks itself into the notch on the stick of memory. For a single stick, we recommend installing it into slot A1 (this should either be written on the motherboard itself, or specified in your user manual)—however, in this configuration, it actually matters very little where you install it. If you're having trouble with compatibility, you can install your stick in any of the slots, and it should perform just fine.

7 COOLER DELAYS

OUR CPU WAS an OEM engineering sample, so we didn't get the retail cooler, and had to use one of our own, which comes with a number of Ryzen gen-2 CPUs. It comes with thermal paste applied, so there's no need to add more. Remove the brackets above and below the CPU socket, and keep the backplate in place. Position the cooler on the backplate, lining up the screws on the cooler with the holes on the mobo. Secure each screw a bit at a time, going diagonally, to ensure equal pressure is applied. If using the included Athlon cooler, leave the plastic brackets in place, and hook the metal latches on the cooler on to them. Rotate the plastic lever on the cooler, and it locks into place. Finally, for both, you install the fan header into the CPU fan header on the mobo.

8 HARD DRIVES AND TIDYING

IN THE ARCADIA, there's only one place to mount the 2.5-inch SSD: above the 3.5-inch caddy mount. With the ports facing back toward your mobo, you install it vertically into the cage, with the screw threads facing toward you. Line it up with the four holes in the hard drive cage, then screw in from the side facing you. Install the SATA power cable (align the L-shaped power connector with the port), then run a SATA data cable from the drive to one of the ports on the motherboard. Locate the front panel headers, and install them into the correct pins on the bottom-right of the board (refer to your motherboard manual for which cables install into which pins). On to cable management. Use cable ties to attach troublesome cables to your case's cable tie loops on the back of the motherboard tray. Then throw the panels back on, and secure them.

9 LINUX TIME

AT THIS POINT, you're going to want to install your OS of choice. For our testing, we had no choice but to go with Windows, because that's what most of our benchmarks rely on. To keep to that sub-$300 budget, though, you're going to want to install your preferred version of Linux—head to www.linux.org for more information. If, like us, Microsoft is your jam, but you can't afford chucking that extra cash at an additional Windows license just yet, you can run an unactivated version of Windows temporarily, and leave your key until a later date. Yes, that does mean you'll have a nasty watermark on the bottom of the screen, but it doesn't mean you won't be able to run your machine. That said, at this level, there's nothing Linux can't do compared to Windows anyhow.

10 BIOS DEBUGGING

DUE TO OUR SYSTEM'S RELIANCE on integrated graphics, it's vital that the motherboard supports the processor ahead of time, and has the correct up-to-date BIOS. If your mobo is powering on, but there's no display, you probably need to update the BIOS. If you have a last-gen Ryzen CPU and free GPU, you can use these to temporarily swap out the Athlon 200GE, install the BIOS update (via a FAT32 USB stick, and the BIOS file from the Asus product page), then swap out the GPU and processor for the Athlon after. Alternatively, contact the reseller or mobo manufacturer, as they might be able to update it for a fee (this requires a return, though). If you're really stuck, go to https://support.amd.com/en-us/warranty/rma, fill in your details, and enter "boot kit required" in the problem description field. AMD will get in contact to send you a loan boot kit to update the board.

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1 **We've tucked the excess cables out of the way below the SSD cage, to keep things tidier.**

2 **If the Athlon isn't your processor of choice, you could easily upgrade to a Ryzen 3 2200G, or even a Ryzen 5 and a dedicated GPU instead—for a few hundred bucks extra.**

3 **We would usually recommend that you run dual-channel RAM as a minimum. Going for a cheaper mobo and doubling the memory would make this rig much punchier.**

THE ATHLON ATTACKS

THAT'S A WRAP. We've got our $285 budget build up and running. As mentioned, we installed Windows to make life easier when it comes to working out how well this machine runs compared to our zero-point. And for the sake of a reasonable comparison, we've changed our zero-point from the usual $1,050 machine to the $482 Intel Core i3-8100 rig we built just over half a year ago. With double the memory and a processor that costs twice as much, it should give us a far better grounding than the Ryzen 5 and GTX 1060 system we usually use.

These builds are always easy to put together. There are five parts inside that chassis, with the only problems being the troublesome rear I/O shield, and deciding how to run the CPU cable. Everything else was a cakewalk.

Getting the thing to run was another matter. After piecing it together, we realized the BIOS hadn't been updated to support the Ryzen Vega chip. That meant stripping it out and, as discussed, popping in a Ryzen 5 1600 and a GTX 1060, just to upgrade the BIOS. Then it was a case of whipping them out and putting the Athlon back inside.

Once that was done, we installed Windows, made sure AMD's chipset was installed (imperative if you want reasonable GPU performance), and continued with the performance testing.

How did it do? Not as well as we'd like. There's no doubt that the Athlon 200GE will be the budget processor of choice, but it's not as game-changing as the Pentium G4568 was when it first launched. We reckon this is in part due to how the two processors are designed. Ryzen's core complex and Infinity Fabric, although ever more impressive the higher up the product stack you go, don't carry much weight in comparison to the monolithic architectural style of the lower-end Intel parts. Once you hit that budget mark, improved latency and better single-core performance carry a lot more clout than complex interconnect fabrics.

As such, it was a little underwhelming. Cinebench R15 scored 355 points in multicore mode, and 126 points in single-core (about the same as a Core i5-2500K). What did impress, however, was the drive performance. Man, that Crucial B500 SSD is something else.

Unfortunately, that 4GB of RAM was a massive limitation in games, with most titles not even loading their benchmarks, due to a lack of memory, both on and off the chip. We did manage to get *League of Legends* running, and it was playable, but anything more demanding, and you'd be out of luck.

Ultimately, our $285 build was an exercise in technical expertise, putting the money where it counts, and seeing what we could do. Are we happy with it? Of course; for light office work, web browsing, and more, it's a fine rig. With a few tweaks, it could be incredible, but that's another story for another day.

BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi (Index)	541	355 (-34%)
CrystalDisk QD32 Sequential Read (MB/s)	540	554 (3%)
CrystalDisk QD32 Sequential Write (MB/s)	372	471 (27%)
Rise of the Tomb Raider (fps)	5	DNF (-100%)
Total War: Warhammer II (fps)	3	5 (67%)
Tom Clancy's Ghost Recon: Wildlands (Avg fps)	2	DNF (-100%)
3DMark: Fire Strike (Index)	1,183	1,069 (-10%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our zero-point consists of an Intel Core i3-8100, 8GB of Team Vulcan DDR4 @ 2400, and a 120GB Kingston SSDNow UV400. All tests were performed at 1080p on the highest graphical profile.

YOU EXPECT a press release to make ambitious claims, but the one from Nvidia for its Turing GPU architecture is particularly striking. The headline tells us that it will "fundamentally change computer graphics," and the company's CEO, Jensen Huang, says that it is "Nvidia's most important innovation in computer graphics in more than a decade." Bold talk, but there's substance behind it. Turing is more than a generational step: It brings genuinely fresh technology to the graphics card, with real-time ray tracing as star billing.

Turing follows on from Pascal, which has powered everything from the top-tier GTX 1080 Ti down to entry-level GTX 1050s. Nvidia also has its Volta architecture, released last year, with its machine-learning cores, but this has been kept to specialist markets, apart from the eye-watering $2,999 Titan V. Turing is aimed at the mass market, although it's starting at the top. It'll run alongside Pascal-powered cards for the foreseeable future.

The Turing architecture has similar clock speeds to Pascal, but increases the CUDA (Compute Unified Device Architecture—small parallel processing units) core count by 15–20 percent. There are improvements to the SMs (Streaming Multiprocessors), and in memory bandwidth, plus a handful of new graphics functions, but the cherry on top is the addition of dedicated RT and AI hardware.

One noticeable change is that Nvidia has launched three Turing GPUs. Pascal cards are built on the same dies, with sections enabled and disabled to suit. Turing cards have launched with three separate dies: the TU102, TU104, and TU106. The smaller TU106 is in the RTX 2070 card, the TU104 in the RTX 2080, and the big TU102 in the halo RTX 2080 Ti, although not yet in a fully functional form. Right, let's start digging around in the transistors to see what there is to elicit such a buzz. Be warned: There are copious acronyms to come.

A LOOK AT THE FUTURE OF GAMING GRAPHICS

What, and why, you need to know about Nvidia's Turing architecture

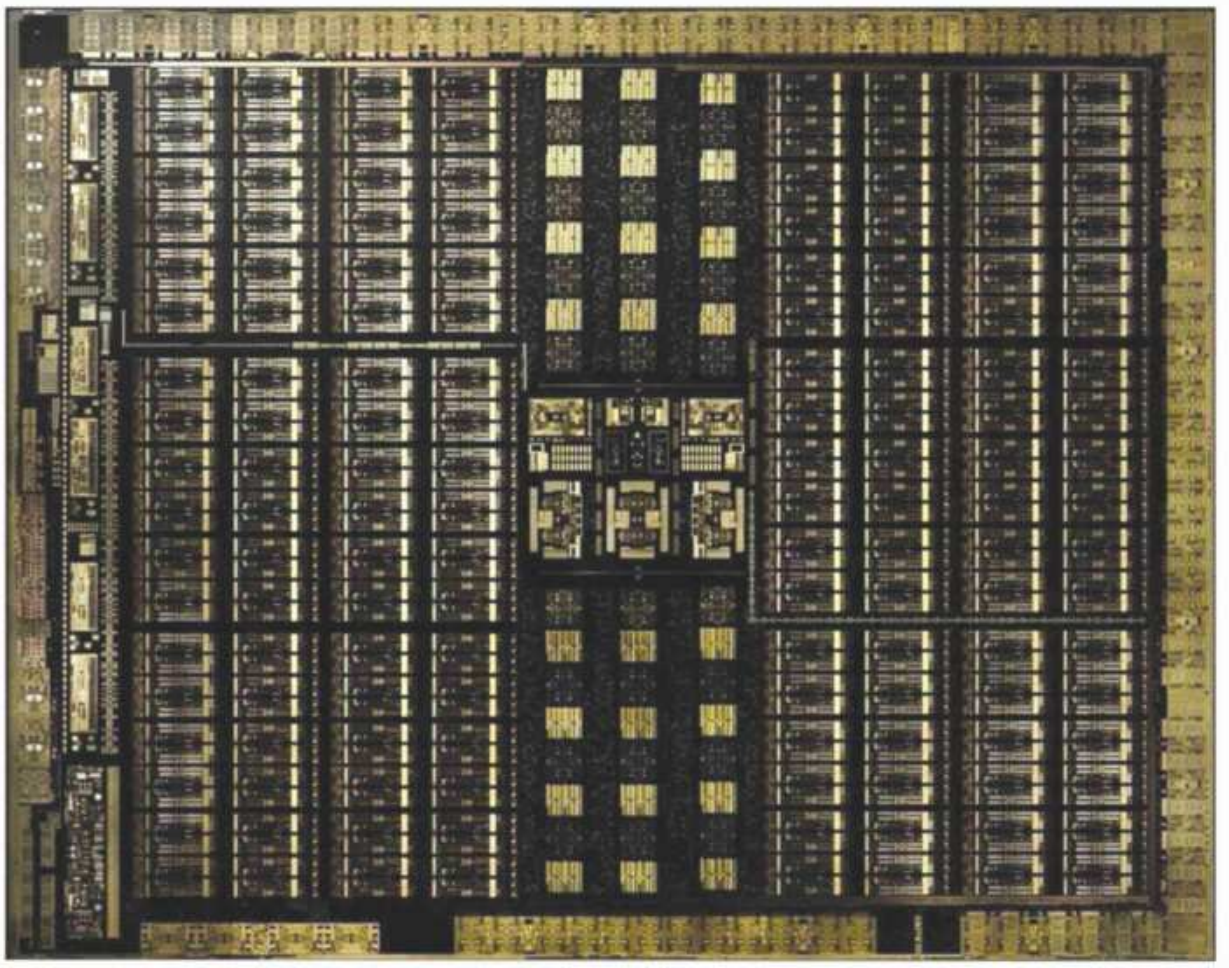
By Chris Lloyd

The 754 x 754mm TU102 is 60 percent larger than the biggest Pascal GPU, with 55 percent more transistors. It's built around six GPCs (Graphics Processing Clusters), each of which has six TPCs (Texture Processing Clusters), along with a dedicated rasterization engine. Each TPC has a PolyMorph Engine (a fixed-function geometry pipeline), and two SMs. Inside these are the cores: 64 CUDA, eight Tensor, and one RT. All clear?

There are 12 32-bit GDDR6 memory controllers, giving 384-bit width in all. Each contains a cluster of eight ROPs (Render Outputs). In the RTX 2080 Ti card, one of these controllers is disabled, giving it 88 ROPs. The layout is not uniform across the dies; the TU104 has eight rather than twelve SMs per GPC, for example, and it, and the TU106, only has eight memory controllers.

At the heart of every GPU is a fundamental building block, called a Streaming Multiprocesor by Nvidia, and a Compute Unit by AMD. It's in here that the majority of the hard work is done. The Turing architecture SM contains schedulers, graphics cores, cache, texturing units, and more.

Starting at the top are the CUDA cores; Turing has 64 per SM rather than Pascal's 128. Over the past decade, Nvidia has had anywhere from 32 to 192 per SM. The company claims that the new architecture is more efficient with 64. Turing adds FP16 (16-bit floating point) support, typically twice as fast as FP32 operations, although not as commonly used in games. We also get two 64-bit CUDA cores per SM, for compatibility support. Volta has 32 of these in each SM, but unless you're modeling a galaxy, that die space is better used elsewhere.



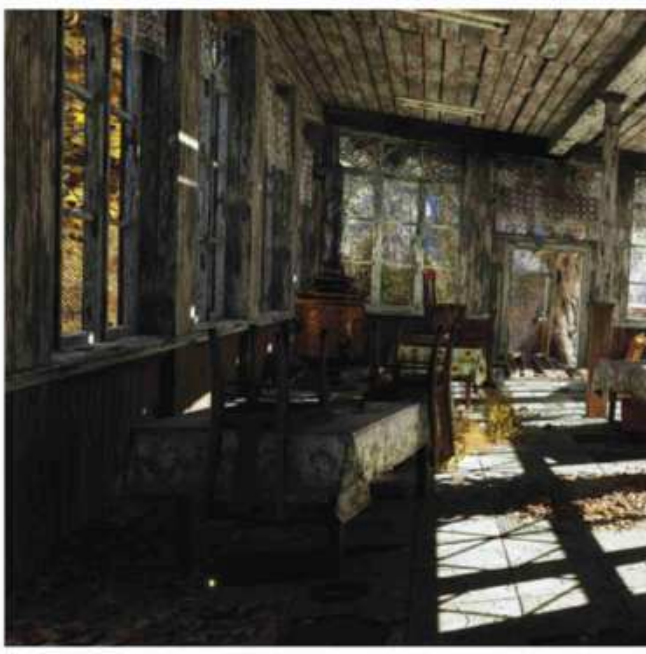
The silicon heart of Turing in all its naked glory. Ambitious, but this is going to change everything, eventually.

New for Turing is a dedicated integer pipeline that can run concurrently with floating-point cores. Nvidia estimates that games have about 35 integer instructions for every 100 floating-point instructions. Previously, all went through the same pipeline, so that's a theoretical improvement of over a third. It makes the GPU core more like a CPU core, which can return two instructions per click. Turing has one of these for every CUDA.

Much of what we've covered so far is present in Pascal, or a subtle evolution of what we already have, but now we get to the genuinely innovative stuff. Inside each SM we have eight Tensor cores and one RT core. The RT core works on the headline ability of Turing cards: real-time ray tracing. This may well produce jaw-slackening results, but the math is fiendish.

The most commonly used ray-tracing algorithm is BVH, (Bounding Volume Hierarchy). This encapsulates objects into large simple volumes. If a ray doesn't intersect with this object, no more calculations need be made. At its simplest, an entire 3D object may be defined as a single box. If a ray doesn't intersect with this box, no more work is required on that ray for that object. If it does, we delve into a hierarchical tree of increasing detail, as the object is broken down into smaller and smaller parts. When the ray does intersect, that branch of the tree is followed. Thus we can get to the intersection point by only checking a fraction of the points on an object.

These calculations can be done elsewhere, on a CPU or GPU, but



NVIDIA GOES 12nm

Much of Turing's advancements are thanks to a die shrink, part of the never-ending quest to be smaller and faster. Turing GPUs are manufactured using TSMC's 12nm FinNET process. In reality, it is more of a refinement of the previous 16nm process than a meaningful reduction of feature sizes. Witness the fact that the TU104 is only slightly smaller than the GP102 used in the GTX 1080 Ti, and the TU106 has 10.8 billion transistors, against a GP102's 12 billion. Despite moving to 12nm, they really aren't much smaller at all. However, it is a mature process, with excellent yields, and it should readily lend itself to faster clock speeds.

The change that will help boost things is a move to 7nm. TSMC is close to full production with this, and AMD's next GPU is supposed to be out and about before the end of the year. If this goes well, we hope to see a more effective shrink of Turing to 7nm. This will get die sizes down to more manageable levels, and enable more cores to be added, and maybe more RT units to really push the ray tracing.

even with BVH optimization, it's a mammoth task that clogs whatever is assigned to it. Enter our RT cores. Dedicated to BVH calculations, these can run through the task about 10 times faster than the CUDA cores, and leave them free to work on other things while doing it.

It is not possible to say precisely how many rays the RT cores can calculate per second, as it depends on the BVH structure. So, performance figures are an approximation. Nvidia quotes the RT cores as capable of over 10 Giga Rays per second on the RTX 2080 Ti, and that each GR/s requires about 10 TFLOPS of computation.

Using a single ray per pixel can result in dozens or hundreds of calculations, and better results are achieved with more rays. If a scene has multiple reflective surfaces, things get extremely complicated. Traditional rasterization has got pretty good over the last 20 years, but certain things still present problems, such as realistic lighting, shadows, and reflections.

Reflections can be faked, but mirrors take serious work, as they require a complete new projection into the game world. Shadow maps can produce decent results, but need a lot of memory to get right, as well as careful placement of lights. Another problem is ambient occlusion, which says how exposed an object is to ambient ligting. Ray tracing masters all these.

Powerful as Turing is, we're still a long way off the required horsepower for true real-time ray tracing. So, like any good GPU tech, we cheat. Hybrid rendering uses traditional rasterization technology

Global ray-traced lighting generates natural lighting and pixel-perfect shadows, with proper umbra and penumbra; here at work in Modus Exodus.

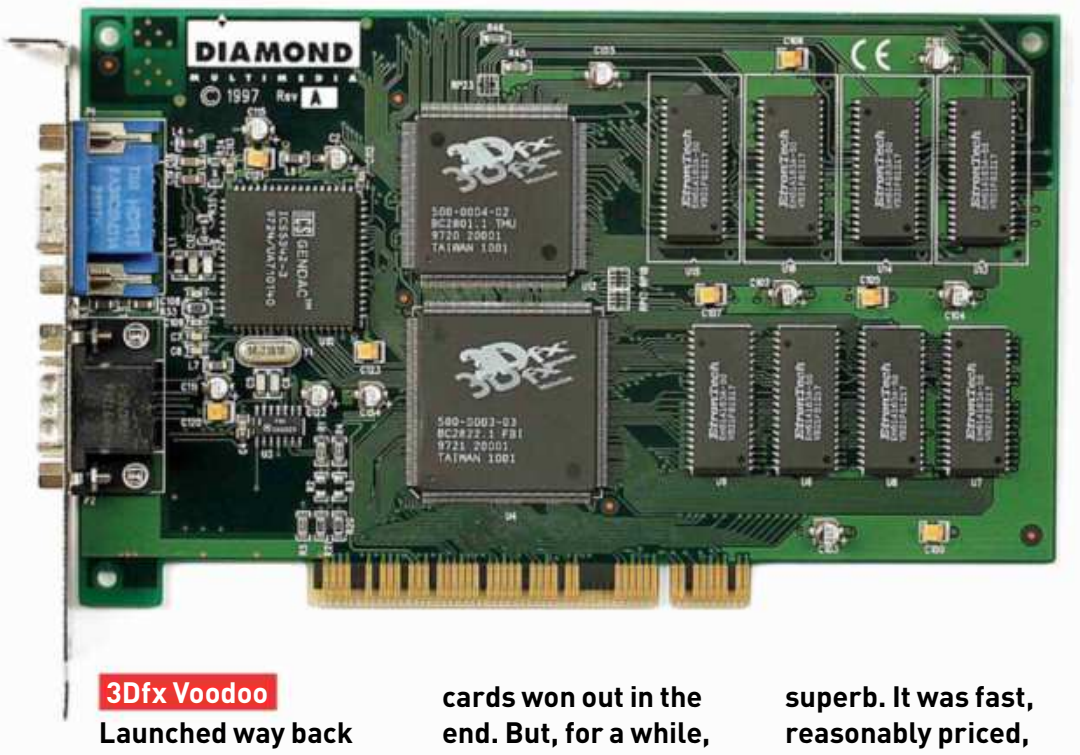
to render all the polygons in a frame, then combines the result with selected ray-traced shadows, reflections, and/or refractions. The ray tracing ends up being much less complex, allowing for higher frame rates. There's a balancing act between quality and performance. Casting more rays for a scene can improve the result at the cost of frame rate, and vice versa.

Taking the GeForce RTX 2080 Ti and its 10GR/s as a baseline, if we're rendering a game at 1080p, that's roughly two million pixels, and running at 60fps means 120 million pixels a second. Doing the math, a game could manage 80 rays per pixel if the GPU is doing nothing else. Move to 4K, and we drop to 20 rays per pixel.

Here is where those machine-learning Tensor cores can help. Nvidia's DLSS (Deep Learning Super Sampling) is trained on a batch of game screenshots on Nvidia's own supercomputer until it learns to do it effectively. The results are packaged into a neat file for the Tensor cores to run locally.

This enables games to render at lower resolutions without antialiasing, then use the Tensor cores to upscale and antialias the image. Or simply as a faster alternative to traditional TAA

GPUS THAT MADE HISTORY



3Dfx Voodoo

Launched way back in 1996, the Voodoo started life in arcade machines, and jumped to the PC when RAM prices fell far enough. It brought decent accelerated 3D graphics to home machines, and was, at the time, simply awesome. It was also expensive, and required a companion card to do all the 2D work. The proprietary API from its arcade machine roots didn't help, either. Technically inferior, but significantly cheaper, and better supported cards won out in the end. But, for a while, it was king, especially when playing *Quake*. No card of merit since could go without accelerated 3D. Thank you Voodoo.

GeForce 256

Nvidia's first true star dates from 1999. The company even coined the term "GPU" to describe its silicon heart. It was the first to provide full DirectX 7 support, now Microsoft had finally coded a DirectX version worth supporting. Its transformation and lighting engine was superb. It was fast, reasonably priced, and swept all before it. Nvidia's climb to the top started here.

Radeon R300

This surfaced in the Radeon 9700 from 2002. It was the first to offer full DirectX 9 support. The jump in performance was huge, especially when antialiasing and anisotropic filters were enabled (it effectively made them usable features). The R300 cards trounced all comers, and three years after launch, it was still a contender.

(Temporal Anti-Aliasing) without upscaling, The results are better, too; lacking the transparency and blurring TAA artefacts exhibits.

Nvidia has shown some interesting demos of games rendered at 1080p, then upscaled to 4K, without the performance hit you'd expect. DLSS has gathered more support than ray tracing, too, with 25 games in the pipeline.

Denoising is another potent tool for ray tracing. Many path-tracing systems are good at creating quick but coarse scenes. Machine learning can reduce the coarse, speckled effect, without the huge computational overhead of running a more complete ray-traced image. Pixar reportedly used such a system to radically reduce rendering times on its animations.

The Tensor cores don't work concurrently with the rest of the GPU, so while they're busy, the rest of the silicon is fairly idle. This limits its use. Nvidia suggests that DLSS and denoising could run at 20 percent of the total frame time.

Helping to boost graphics performance is pushed as the Tensor cores' main benefit, but there's more they can do. Nvidia and Microsoft have created the DirectX Machine Learning API. Future games could use all sorts of AI tricks, such as voice control and more devious AI opponents.

These changes have meant that comparing performance between different generations of GPU has become complicated. For existing games that don't use the new features, the old FP32 TFLOPS figure is a reasonable measure, but once you add hybrid ray tracing, it doesn't fit the job, so Nvidia has devised a new metric: RTX-OPS.

Obviously, this measurement will favor RTX GPUs. In a game that makes full use of ray-tracing effects, the workload is distributed as follows: 80 percent running FP32 shading (what games currently spend time on), with 35 percent of that time on concurrent INT32 shading. Ray tracing is used for 40 percent of the time, and the output is processed by the Tensor cores for 20 percent of the time. This final polish is the only thing running at this point, as the Tensor cores need the GPU's full attention.

Using this formula, we have an RTX-OPS figure for the Founders Edition of the RTX 2080 Ti of 78 RTX-OPS. How would a GTX 1080 Ti fare? It lacks the RT and Tensor cores, and can't run the integer and floating point together, so its RTX-OPS score would simply equal its TFLOPS score of 11.3. This looks lack-luster, but it's apples and oranges: The RTX-OPS value is only of interest if you are running a hybrid ray-tracing engine.

Ansel RTX is a neat screen grab utility that enables you to crank up the ray-tracing horsepower when you take a screenshot. It'll also do clever AI upscaling in non-RTX games, pushing screenshots to 8K.

To keep its new GPUs fed with data, Nvidia has moved its Turing cards to GDDR6 memory, and reworked the cache and memory subsystem. The L1 cache bandwidth has been doubled, and can now run as either 32K of L1 and 64K shared memory, or as 64K L1 cache and 32K shared. The L2 cache has been doubled, too.

The faster clock speeds of GDDR6 over GDDR5 help, but Turing goes further. Pascal already used lossless memory compression, and Turing has improved on this. Nvidia hasn't provided details, but claims that the larger caches and improved compression have increased the effective bandwidth by 20–35 percent over Pascal.

Turing introduces a number of new functions, too. How much these are used is another matter. Nvidia's VXAO (Voxel Ambient Occlusion) has, as far as we know, only been used in two games in two years.

Who doesn't like a block diagram of new silicon? Here's the TU102 core laid out and color-coded, showing its tightly integrated design.

Foremost of the new features is Mesh Shading, the next iteration of vertex, geometry, and tessellation shaders. The idea is to move the LOD (Level of Detail—we weren't kidding about the number of acronyms) from the CPU to the GPU. There are some impressive demos of this. It needs to be implemented at the API level, so must be built into DirectX/Vulkan before it can become widespread.

Next is VRS (Variable Rate Shading), which is about moving processing power to where it can have a tangible effect. Here it uses more shaders in important areas, and fewer where results are negligible. Nvidia suggests a 15 percent performance boost when used effectively. It can be used as part of MAS (Motion Adaptive Shading), where fast-moving objects need less work as they look blurred anyway, and CAS (Constant Adaptive Shading), where effort is focused on primary content, on the car in a driving game, for example.

Nvidia talked about two further features of Turing: MVR (Multi-View Rendering), an enhanced version of the Simultaneous Multi-Projection that was already in Pascal, and TSS (Texture Space Shading). Where SMP focused on two views and VR applications, MVP can do four views per pass, and removes some view-dependent attributes. It should help improve VR applications, especially with some of the newer VR headsets that have a wider field of view. TSS is another method for reducing the shading required,

and really only of interest if you are writing a game engine.

And finally, we have a boost to video encoding/decoding. Pascal wasn't bad at this, but the results weren't always as good as the x264 Fast profile running on a CPU. Turing aims to deliver better than x264 Fast, with almost no CPU load. If you're streaming at 1080p, it won't matter too much, as Pascal or a good CPU can cope, but move to 4K, and you risk dropped frames. Turing aims to serve 4K encoding with almost no CPU load.

Are we impressed? It is difficult not to be. The Turing architecture is a masterpiece from the leading graphics technology company. It's the result of 10,000 engineering-years of effort (says Nvidia). Not only do we get a decent step up in the classic GPU architecture, we get features that change the way graphics are realized. The hybrid approach, fusing rasterization with real-time ray tracing, and adding AI-powered processing enables something special. The road to full real-time ray tracing is here, years before most expected it.

We have the hardware, now we need the support. The current list of games is small, a dozen or so, but emerging tech generally starts small. Ray tracing is a better way to render scenes, and the prospect of using it in games, however partially, is too tantalizing to resist. Big names have lined up behind Turing, including Epic, with its Unreal Engine, and EA's Frostbyte. Microsoft has plumbed ray tracing into DirectX, giving the all-important route to standardization.

At some point in the next few months, or maybe more, you are going to see a game that pushes the graphics to such a point that you're going to want a card that can run it, and want it very badly.

The GeForce RTX 2080 Ti Founders Edition—yours for $1,199, and limited to two per customer. The most expensive GeForce card ever, and the fastest.

WHAT CAN I PLAY ON IT NOW?

Hey, it's still early days, but here's where Nvidia says you can enjoy ray tracing now, or very shortly.

Battlefield V

This is said to be one of the best places to start to showcase Turing's abilities. Ray tracing is used to make lighting effects bounce around the environment. Muzzle flashes and explosions really pop, and there are some lovely reflections, as you can see in the supreme example above. It's due by late November.

Shadow of the Tomb Raider

This uses a more subtle approach, with the emphasis on generating softer and more natural shadows. Available now.

Assetto Corsa Competizione

Some impressive ray-traced reflections, shadows and ambient inclusions. It's on Steam's Early Access now.

Metro Exodus

This boasts of ray-traced global lighting and ambient occlusion for pixel-perfect shadows. Unfortunately, it's not due until next February, though.

Enlisted

WWII-themed MMO due to launch next year with global illumination. It's free to play, too.

MechWarrior 5

The MechBay is to feature lighting, shadows, and reflections; there may be more ray-traced features to follow. It's due at some point next year.

Control

An action-adventure that uses elements of ray-traced reflections, global lighting, and shadows to boost its own graphics engine. It's due sometime next year.

Atomic Heart

This weird FPS boasts ray-traced shadows and highlights, and some lovely shiny things in its creepy alternate universe. It's due late next year.

Justice

A huge MMORPG from China, currently in beta testing, RTX support is promised.

JX3

Another huge Chinese MMORPG that's promised RTX support at some point—details aren't that forthcoming yet.

Project DH

A steampunk RPG that's been stuck in development for quite a while now—no firm dates on release, or the level of RTX support.

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TECH PORN

1 MULTI-SYSTEM

With a special bracket, the Evolv X can support two systems at a time: A full-size E-ATX setup and an ITX system can be housed in the same unit. Combine it all with a Phanteks Revolt X dual-system PSU, and you're good to go.

2 STORAGE SOLUTIONS

Hypothetically speaking, with enough caddies, you could fit a total of 10 3.5-inch drives, plus nine 2.5-inch drives. Yep: 19 drives in total in one machine. OK, that's a little excessive, but any combination of storage is possible in this beast.

Phanteks Enthoo Evolv X

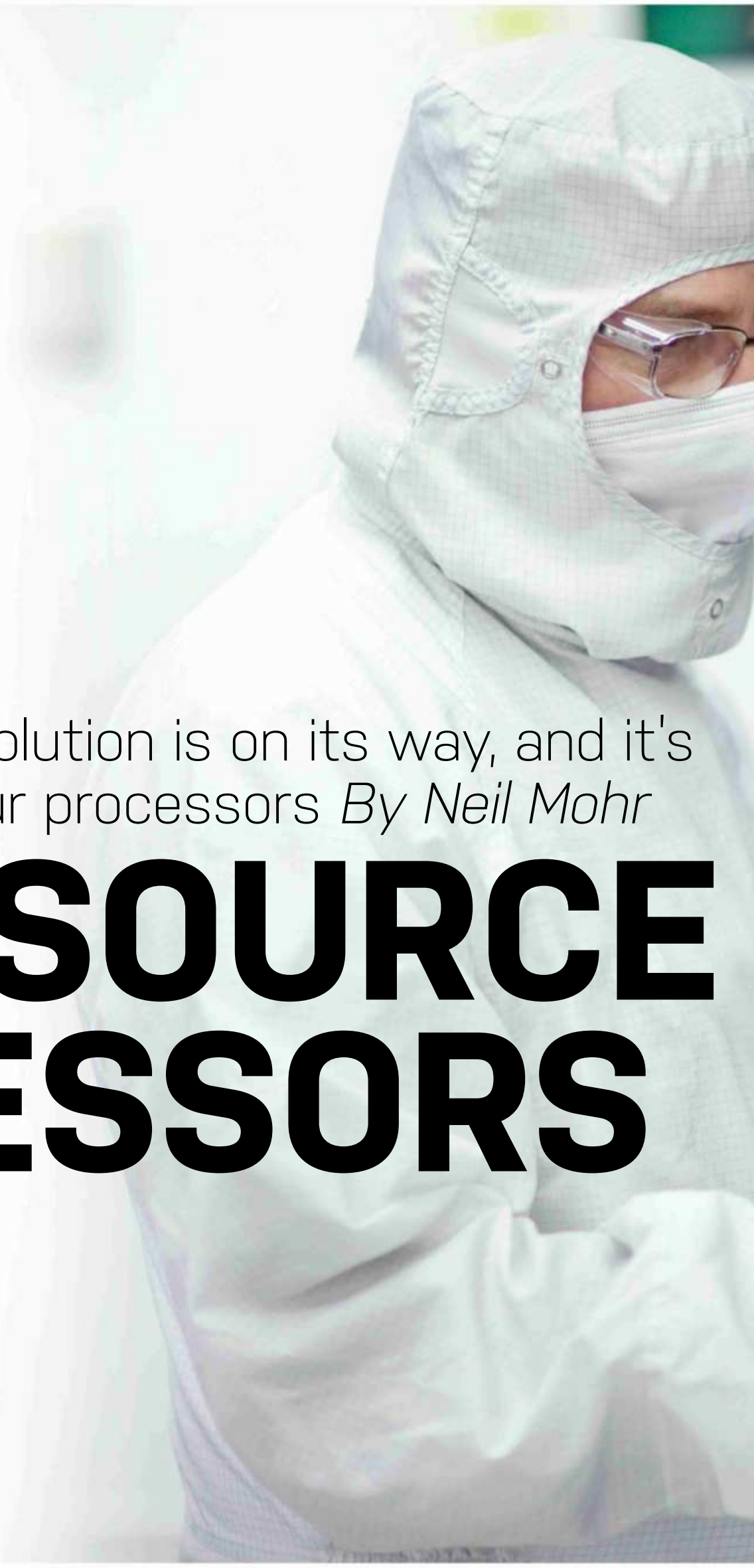
IT'S NO SECRET THAT PHANTEKS has produced some of our absolute favorite cases of all time. Its attention to detail, use of high-quality materials, and innovative design philosophy has forged some true gems when it comes to those rectangular boxes our systems call home.

As for the Evolv X? Well, it's an evolutionary step up from Phanteks's original Evolv. This mid-tower monster takes all the features of the original Evolv, and improves upon them. From enhanced airflow to better spacing, superior tempered glass panels, now fixable in place, and those intuitive rear hard drive caddies, it's a case to be admired. Of course, there's also the added inclusion of some smooth-flowing RGB, all digitally controllable and ready to go, and superb cooling support. Oh boy, it's a liquid-cooler's dream, that's for sure.

So, what's the catch? What's the price of this beautifully crisp, clean sophistication? Weirdly, there isn't one, really. These additions have been added at minimal cost to the end user. In fact, compared to its predecessor's price on launch, this goliath of sand-blasted aluminum and powder-coated steel only costs $10 more. Sure, it will still set you back $200, but for what you get, it's more than worth it. **–ZAK STOREY**

3 LIQUID LUXURY

From integrated drain and fill ports to support for up to 920mm of radiator in total, the Evolv X is a wizard when it comes to keeping even the hottest parts cool.



An open hardware revolution is on its way, and it's coming to conquer your processors *By Neil Mohr*

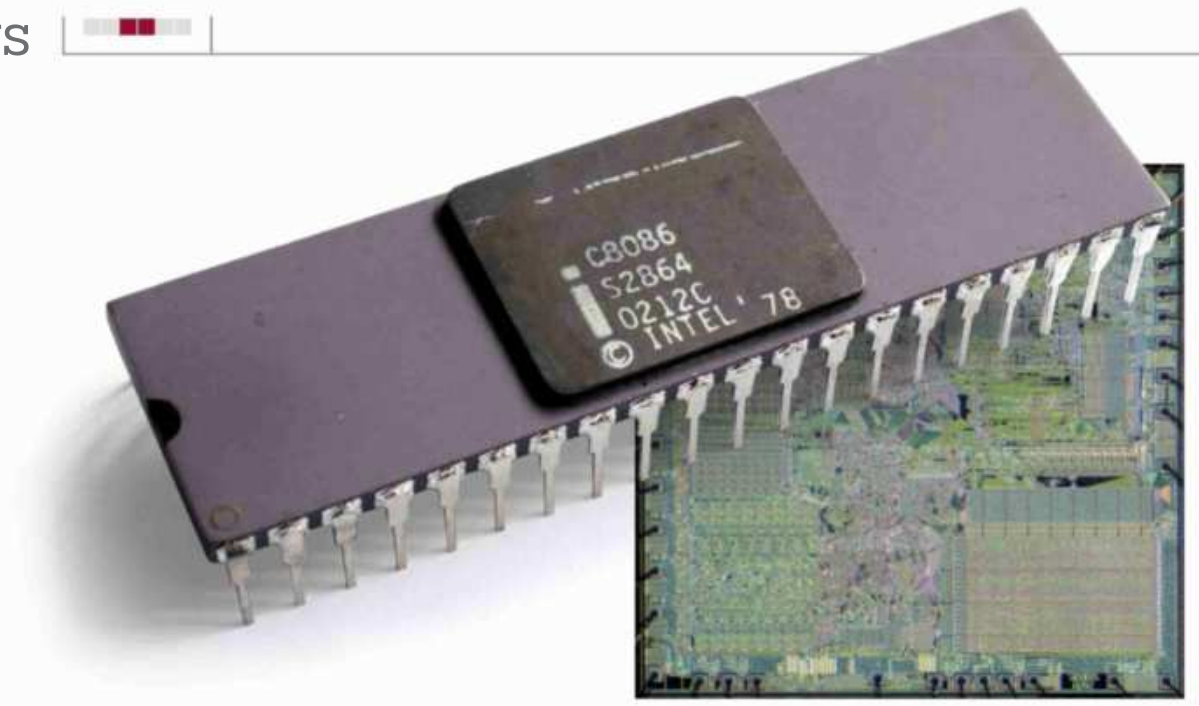
OPEN-SOURCE PROCESSORS

MONOPOLIES AREN'T BAD. At least, they don't have to be. But with a single corporation owning the rights to the x86 instruction set, the consumer processor market is hardly abuzz with competition. It's true enough that AMD's star is currently on the ascent, but that's been helped by a decade of stagnation by Intel, ever since the heights of the original Core 2 releases. The situation is an indication, though, of what would happen if x86's only competitor dropped out of the processor market—Intel could stop all development, and you would still have no option but to buy its processors.

It isn't healthy to over-specialize. "But there's ARM!" you rightly cry. ARM is a peddler of intellectual property, though. The company licenses its design, and manufactures nothing itself. It's a healthier arrangement—there's a range of competition, big and small—but the license fees are far from trivial.

Of course, this is hardware—people can't just give it away for free, like software.... Or can they? Just as the open-source Linux kernel has ultimately triumphed over all other competitors (in certain areas, anyway), it's now the turn of open hardware to have its day.

So, how is this revolution going to happen? What devices are we going to see powered by open hardware? And when is this change going to occur? To answer these questions in a meaningful way, we're first going to have to delve into what actually makes a processor tick, before considering what's actually needed in this day and age of the Internet of Things?



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The original Intel C8086 chip that defined the x86 architecture, alongside a die of 29,000 transistors whizzing along at 5MHz.

Ones and zeros. At their heart, processors are pretty simple engines; so simple, you can recreate one inside *Minecraft* (http://lazcraft.info/tagged/CPU). There are registers to store instructions, data, and results. There's a program counter that moves everything along to the beat of the processor clock. A control unit decodes fetched instructions, shifts data, and co-ordinates the pipelines that execute individual instructions. Bolt on a cache and memory, and you're pretty much there. We've designed a processor—now, where's our money?

The element that really defines this architecture is the instruction set—the ISA, Instruction Set Architecture. As you might imagine, this can get complicated. The original design philosophy, if you can call it that, for processor instructions is known as Complex Instruction Set Computer, or CISC. We're being dismissive, because when x86 was being devised, instructions were chosen and added as needed, building on top of the 1972 8-bit 8008, but really starting with the 1978 8086, and onward.

It was later, out of a university project at Berkeley, that the Reduced Instruction Set Computer, RISC, philosophy was created, between 1980 and 1984. The realization was that a compiled version of Unix used only a third of the available CISC instructions. The obvious move was to concentrate design effort on those few instructions, to make them run as fast as possible.

The reduction in complexity was astounding: The RISC II architecture from Berkeley was implemented with 39,000 transistors; the CISC Motorola 68000 produced around the same time, and which powered the Amiga 500, used 68,000, but the RISC II design ran up to 420 percent faster. The Intel 80286 also manufactured around then used 134,000 transistors, and ran far slower than either.

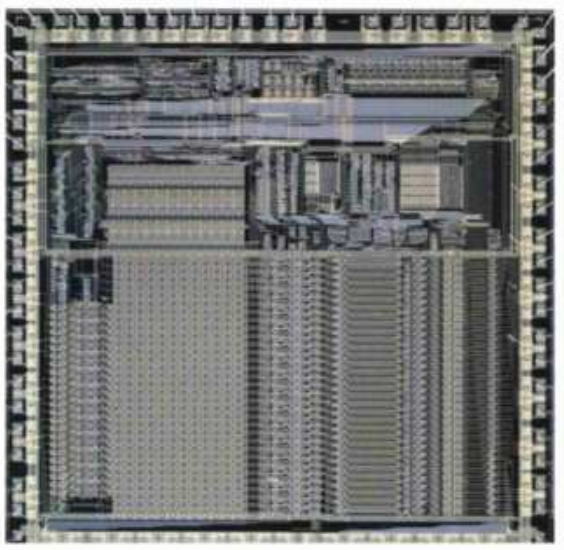
The interesting part of this bit of computing history is that while consumer PCs consolidated around Intel's x86, the high-performance computing market fell in love with RISC designs. SUN Sparc was the industry leader, but there was DEC Alpha, IBM Power, and MIPs (these last two are still going strong), to mention just the leaders at the time. So while, in 1992, Intel had its 486DX2 at 66MHz managing 25MIPs, Alpha had its 150MHz 21064 pumping out 86MIPs, and the confusingly named MIPs had its 150MHz R4400 managing 85MIPs.

We should also mention an obscure UK outfit called Acorn Computers, which at the time (1981–1994) was manufacturing the BBC (as in the UK's state broadcaster) Microcomputer. In 1983, it took the radical decision to develop its own 32-bit RISC processor architecture called ARM to power its next computer model. If that name isn't familiar, ARM now powers tens of billions of mobile devices.

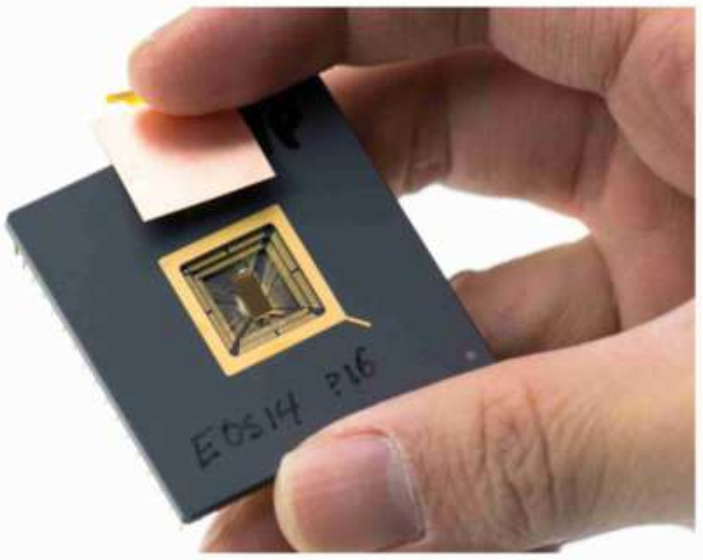
At this point, no one would blame you for thinking this was a feature on RISC, rather than open hardware. What we've been doing is looking at the background of why open hardware is needed. And that background is one of ever-reducing options, not just for consumers, but for developers, manufacturers, and

THE BASE DESIGNS		
RV32I	32-bit integer instruction set	v2.0 frozen
RV32E	32-bit embedded integer instruction set	v1.9 open
RV64I	64-bit integer instruction set	v2.0 frozen
RV128I	218-bit integer instruction set	v.17 open

EXTENSIONS AND THEIR ASSOCIATED NAMING		
M	Integer multiplication and division	v2.0 frozen
A	Atomic instructions	v2.0 frozen
F	SP floating point	v2.0 frozen
D	DP floating point	v2.0 frozen
G	Shorthand for the base above extensions	
Q	QP floating point	v2.0 frozen
C	Compression instructions	v2.0 frozen
B	Bit manipulation	v0.36 open
P	SIMD instructions	v0.1 open
V	Vector instructions	V0.2 open
N	User level interrupts	v1.1 open



Where the ARM RISC architecture began.



An early RISC-V prototype from 2013.

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The Summit supercomputer is RISC-powered with the IBM Power9.

innovators. The last decade of the 20th century was vibrant for the processor market, with multiple vendors selling multiple architectures. So what happened? Intel kept driving its fab technology, which eventually gave it enough transistors to optimize its x86 architecture—x86 in post Pentium Pro designs is decoded to an internal RISC microcode—and push out all competition. The main downside of the pursuit of power is that it consumes more energy, which is fine when your target is servers, workstations, desktops, or even bulky laptops. But jump forward four decades, and the emphasis is on low-power architectures for cell phones and ultra-mobile laptops, and Intel's x86 simply can't complete with ARM and its RISC design. A lazy way of putting this is that it requires more transistors to decode an x86 CISC instruction than an ARM RISC one, therefore x86 consumes more power per instruction. It isn't the only reason why Intel has failed to make an impact in the ultra-mobile market, but it's a major one.

So, all we've done is swapped one monopolizing architecture for another—big whoop. You can argue that ARM is a better competitive landscape, in that anyone can license the ARM architecture and sign its required NDAs, if they want to and can afford it. With x86, there's just Intel, AMD, and VIA that can design and sell x86 processors; we believe IBM can produce processors based on the 80486 architecture, but it's legally complicated, and there have been lawsuits.

An open hardware processor promises to do away with licenses and processor monopolies. It might sound like a pipe dream, but a solution that you can buy already exists. It's called RISC-V (http://riscv.org) and it was developed at Berkeley University, the birthplace of RISC.

Established during the summer of 2010, RISC-V (fifth-generation Berkeley design) sets itself apart from other processor designs for a number of key reasons. The first we've already covered: It's an open design, licensed under the open-source BSD license. Another key difference is that previous open architecture designs focused on being simplistic, to ease understanding for academic teaching, rather than being robust and optimized for practical commercial deployment. RISC-V also has all the required commercial-level software tools in place; the instruction architecture, for example, is fully implemented in the open-source compiler GCC. All the components to boot an OS, such as Debian Linux or FreeBSd, have been in place since the start of 2016, including the important U-Boot and UEFI specification support.

These are the required firmware and software tools you need to compile an operating system and software for the platform, with the firmware to boot-strap a system from cold, load the UEFI system, and hand over to an OS kernel. Boom! An entire open system.

So what is RISC-V, and when is it going to be running our desktop/laptop/robot-overlords? At its heart, RISC-V is an open, extensible processor architecture. There's a base fixed set of definitions, with

THE OPEN WAY

Let's change tack and talk about open-source software and Linux—stop groaning at the back! You won't be running desktop Linux, and that's fine, we're not here to convince you to, but the majority of the world's servers and virtual machines do run Linux. Why?

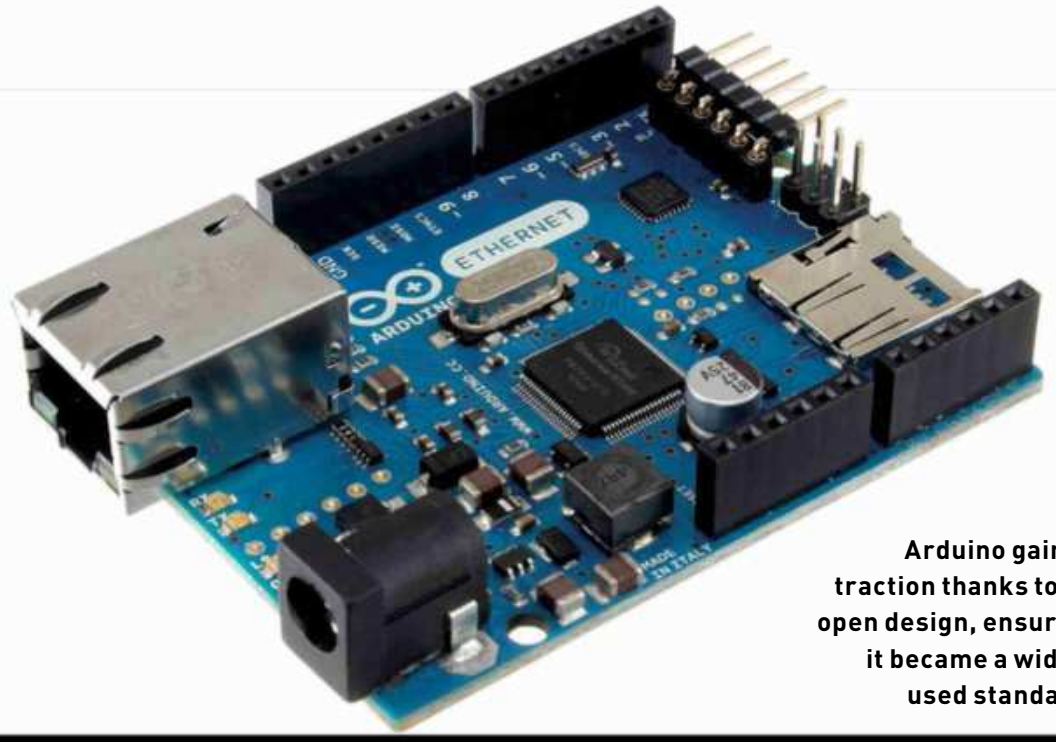
This sounds like a contradiction, but it's not because the software is free (technically, yes it is, but it costs to deploy and support it); it's because the software has been freed under the GNU GPL (General Public License).

Back in the day, Microsoft required a Windows license for every physical processor in a system. Think about that for a moment. For your desktop, who cares? But even modest workstations have dual CPUs. And what about enterprises that run warehouse-sized server installations? Even worse, what do you do if you want to spin up infinities of virtual hosts on the fly?

The open license nature of Linux, and the associated open-source software ecosystem, just makes everyone's lives easier when it comes to deploying it in complex environments. Even if there were no cost savings, that alone made it compelling for business—but that was just one driving factor.

The same issues and more applied to academia and research: Not only the freedom to use the software, but to study, research, and modify the source code at will, with no restrictions—other than the stipulation of the GPL to share your changes back.

This creates a venerable feedback loop of development: Students study and enhance the Linux kernel, businesses utilize and optimize the kernel, researchers explore and develop entire new systems. The students move on to the professional world, taking their open-source work and ideas with them, and so on. It's this type of progress that eventually leads to every single supercomputer in the world's top 500 running Linux (www.top500.org/statistics/overtime). Perhaps RISC-V will experience the same....



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Arduino gained traction thanks to its open design, ensuring it became a widely used standard.

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AN OPEN DREAM

There are certainly precedents for open hardware being successful, even if that comes with a few hiccups along the way. One of the better-known projects is Arduino, an Italian-designed microcontroller range that has its software and hardware designs licensed under Creative Commons. The schematics and designs for the boards have open licenses, even though the Arduino name itself is trademarked. In fact, there was a legal spat between the founders over the trademark, but thankfully that was resolved in 2017. Arduino's open nature has enabled it to flourish as a core component in the more niche maker area, because it enables smaller specialist hobbyist companies to manufacture Arduino-compatible boards.

Certainly, part of the RISC-V initiative is to deliver an open ecosystem in line with Arduino, alongside the open-source software. An additional motivation is that an open processor is a core building block toward a fully open PC design. Privacy advocates abhor locked-down hardware provided by Intel and AMD, alongside Nvidia, where you have no idea what its internal microcode is actually doing. This extends to cell phone radios, Wi-Fi, and more. They argue that an evil actor—i.e. the Deep State—can force companies to insert any code they wish into these systems. The aim is to have a PC system where every code element is open to scrutiny. If you're thinking "tinfoil hat," the NSA was seen intercepting Cisco routers and flashing its own firmware on to them in 2010: https://arstechnica.com/tech-policy/2014/05/photos-of-an-nsa-upgrade-factory-show-cisco-router-getting-implant/

various open extensions. It supports 32-, 64-, and (as yet unused) 128-bit instruction word lengths (see table, pg. 50—a RISC-V processor aimed at the desktop might be named RV64GC, for instance).

The base design allocates a 16-integer register, with R0 always returning a zero, which can be a standard design tool. The floating-point extension adds an additional 32 float registers on top. Instructions can only access registers, which again is a standard RISC design.

Interestingly, RISC-V turned out to be unaffected by the Spectre and Meltdown hardware prediction security flaws, which affected Intel, AMD, and more recent ARM processors, mainly because the RISC-V design team rejected complex branch prediction, arguing it increases processor complexity and power consumption.

To start, it uses a simplified number of conditional instructions; it offers ten branch operations across just six instructions, which work over shorter branches, just 12 bits from the program counter. The design then encourages compilers to optimize for standardized branch predictions: Backward conditions should be taken, forward should not. This ends up with larger compiled code, but a faster hardware implementation.

Certainly, at this stage RISC-V lacks a number of instruction areas that desktop and server users take for granted, but they're being worked on. For desktop users, we're used to SIMD being available to accelerate multimedia and digital signal processing. The packed-SIMD extensions are still being developed; the idea is that single instructions could process 64 bits of data stored across four 16-bit registers.

Interestingly, there is resistance to the addition of SIMD, with some saying it is a poor use of processor resources, and it would be better to concentrate on vector extensions. A full vector extension could potentially be implemented within the default register set, be more flexible than a SIMD extension, and ultimately execute as fast, if not faster. There is a solid argument here, as anyone who remembers MMX, MMX2, 3DNow!, 3DNow! 2, SSE1/2/3/4, AVX, and so on can attest. The danger is an ever-growing instruction set, which goes against RISC, rather than a fixed, flexible vector set.

WILL IT PLAY CRYSIS?

No, it won't—stop asking. It's still very early days for RISC-V, but there are products on the market. They are, however, aimed at makers, embedded projects, and research markets. Take SiFive (www.sifive.com): It shipped the HiFive1, an Arduino-style microcontroller using a RISC-V processor (RV32IMAC—go check those codes), in the middle of 2017. Benchmarks (running at 256MHz) showed it outperforming an ARM Cortex-M4 and Arduino Micro, on a MHz for MHz level, all for $69.

More interestingly, in mid-2018, SiFive shipped its HiFive Unleashed. It might have cost $999, but this development board was capable of running desktop Linux, and used a quad-core 1.5GHz RISC-V RV64GC architecture. Each core uses a five-stage, single-issue, in-order pipeline, backed by 32KB L1 instruction and data cache, and 2MB L2 cache. The interesting part is that you can download every element of the design—the schematics, bill of materials, and processor design files.

At this early stage of development, it seems silly to compare performance;

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A host of RISC processors saw commercial success from the late 1980s into the 2000s.

the single-issue and in-order design is going to peg the performance below any ARM Cortex-A5x processor, which is out of order with branch prediction. Indeed, tests of the HiFive Unleashed show it running 4–10 times slower than the 2GHz Nvidia Jetson TX2.

The Nvidia SoC shows the sort of competition RISC-V, as an architecture, is up against. It's not enough to deliver a working processor core; these days, people expect a host of connectivity to come with it, from memory controllers and PCIe buses to Bluetooth and wireless and wired networking. All of these come with their own controllers and patents, so the dream of building a truly open hardware platform is an uphill struggle, but it's one that can be overcome.

RISC-V is certainly attracting industry attention—current Platinum members of the RISC-V Foundation include Google, HP, IBM, Oracle, Microsoft, Nvidia, and Qualcomm. At the seventh RISC-V workshop at the end of November 2017, Western Digital announced that it was planning to transition a billion cores per year to RISC-V design, for data center and edge computing.

It's a bold statement from a big player, but its implementations will be, at best, low-end processors running in embedded controllers, which could certainly deliver a cost and competitive advantage to WD down the line. It's all early days for RISC-V, but like the Linux kernel, which was also dismissed at the time, once academia, researchers, and businesses start using and enhancing your open design, world domination is just a decade away.

If we were Intel, we'd be worried, and it seems ARM is already circling its wagons. But RISC processors are puny and weak, aren't they? You forget how powerful they were in the early nineties. Up until 2018, China had the fastest supercomputer in the world, built entirely around ARM RISC processors. It's planning three new models for 2020, again x86-free. Japan has a similar design using ARM processors for 2021. Even the recent USA Summit supercomputer gets the majority of its computing power, not from the IBM Power9 RISC processors, but from Nvidia's Tesla V100 units. While Intel or AMD will undoubtedly be powering your desktop through the 2020s, with ARM inside your mobile devices, we'd be surprised if RISC-V wasn't appearing in all manner of embedded devices, even some mobile ones, and perhaps moving to the data center. Your desktop could be next.

SPEED AND BENCHMARKS

We can't emphasize enough that benchmarks are largely irrelevant at this point, as RISC-V implementations are going to be targeting embedded, low-power, controller and enthusiast boards. No one is going to be releasing a consumer-level laptop or desktop at this early stage. There is a question, though, of how efficient the ISA is versus other commercial implementations.

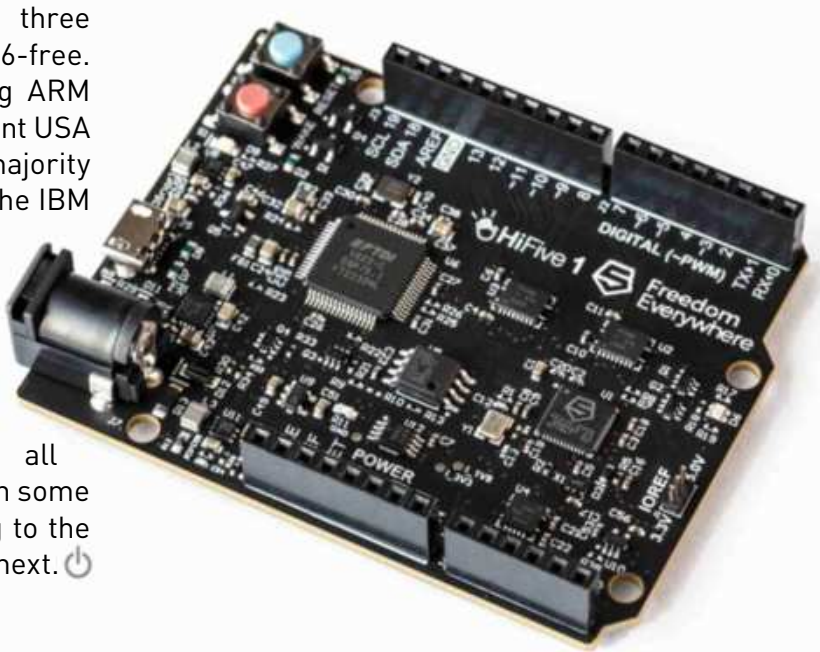
A thorough micro-op analysis of, say, x86-64 versus RISC-V compiled binaries is the sort of thing good PhD theses are made from. In fact, that was exactly what was done back in 2016; you can see an outline of the report on YouTube (www.youtube.com/watch?v=Ii_pEXKKYUg), which shows RISC-V binaries are competitive in micro-op density, and can outperform x86 and ARMv8 code, with a number of potential compiler optimizations being highlighted from the study.

For a more layman's level look, we'll take the ancient integer-based Dhrystone benchmark. It may be getting on a bit, but it's been tweaked to mitigate against hardware and compiler cheats, while it's suitable to use as a rough guide for performance across differing hardware architectures.

The standard measure is millions of Dhrystones per MHz, aka DMIPS/MHz. It roughly scores how much work a single core can do per MHz clock. It obviously doesn't count accelerated vector or SIMD instructions; think of it as a standard program benchmark. We've listed a range of processors—the one we find of interest is the Atom N455, as this is a modern in-order x86 architecture. It clearly has work to do to catch up ARM; Cortex A53 is an eight-stage, dual-issue in-order architecture and, running on the Raspberry Pi 3, is significantly faster.

PROCESSOR	MHz	DHRY2 Opt	DMIPS/MHz
80486 DX2	66	18	0.27
Pentium	100	78	0.78
Pentium Pro	200	164	0.82
Atom N455	1,666	2,704	1.62
Atom Z8300	1,840	3,201	1.74
HiFive Unleashed	1,500	2,625	1.75
ARM v8-Cortex A53	1,200	3,536	2.95
Core i7-4820K	3,700	23,607	6.38

Expect to see RISC-V running microcontrollers all over the place.



MAKE YOUR OWN PROJECTS WITH THE RASPBERRY PI

Learn the electronics, computing, and coding skills you need to make your own projects with the Raspberry Pi, and let your imagination run wild

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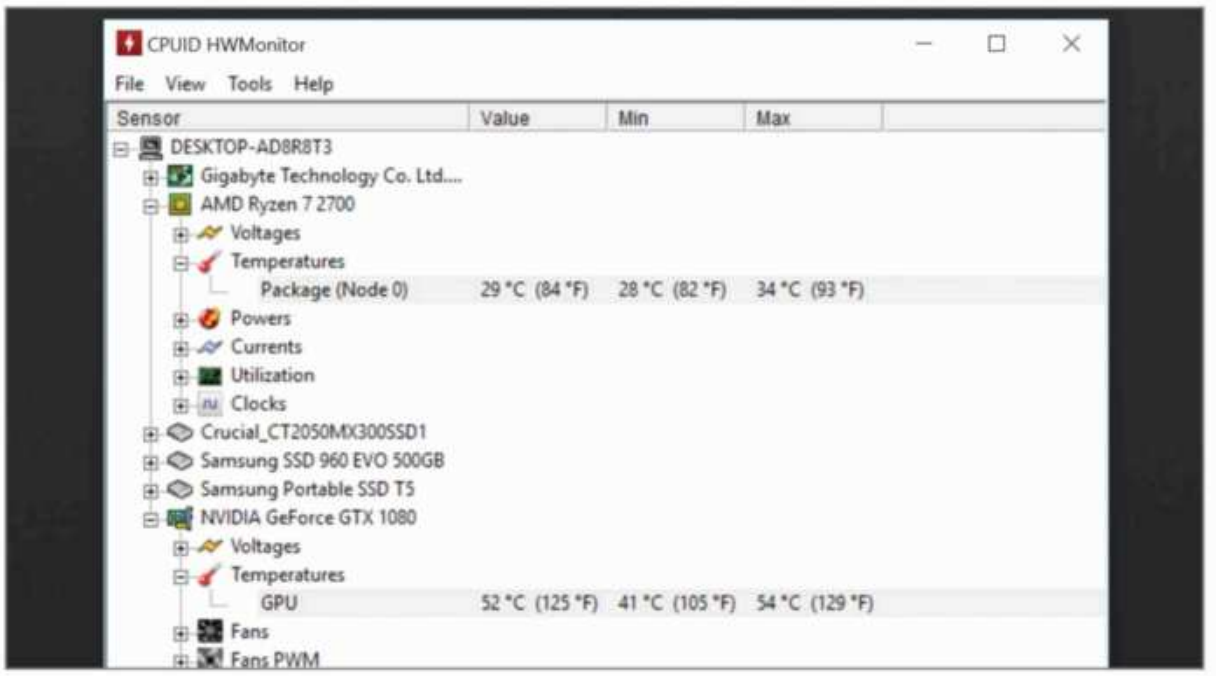
HOW TO

STEP-BY-STEP GUIDES TO IMPROVING YOUR PC

TIP OF THE MONTH

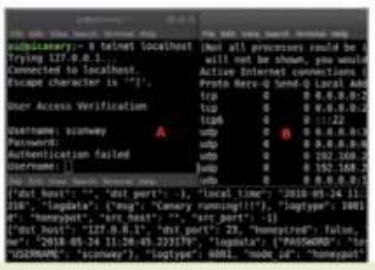


MEASURING TEMPERATURE

There's a whole plethora of ways of measuring the temperature of your processor and parts, but our favorite tool by far is HWMonitor. Simple, free to download, and developed by the same guys and gals who work on CPU-Z, it can provide you with all the sensor information you could possibly need, from current to temperatures, load, and more.

$Free https://www.cpuid.com/softwares/hwmonitor.html

MAKE – USE – CREATE



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Honeypot role-playing for the Raspberry Pi

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Create a pop-art portrait using Adobe Photoshop

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Tracing the rays of the future with an RTX 2080 Ti build

ZAK STOREY
DEPUTY EDITOR

THERMAL PASTE SAGES

I was watching an interesting video from the guys at Gamers Nexus with regard to thermal paste. Notably, what effect your application method has on temperature with a mainstream processor. And it confirmed a lot of what we thought to be true.

What were the results? Well, they discovered that the application method and amount of paste used made little to no difference on temp results (less than 1 C between five different methods, in a strict testing environment). We expected as much. In our labs, for our mainstream parts, we typically opt for a small pea-sized dot in the middle, then let the heatsink spread it out over the die.

What we're getting at is this: However you apply your thermal paste, as long as there's a layer of it between the CPU and the heatsink, you're good to go. There are exceptions, especially if you're using a larger multi-die or monolithic HEDT chip, or an excessive amount of conductive thermal paste (if that stuff falls out the sides, you could be looking at a short circuit), but otherwise, for mainstream method, the amount simply doesn't matter. For the full breakdown and in-depth testing, I recommend you check out Gamers Nexus's video at http://bit.ly/GNThermalPaste.

↘ submit your How To project idea to: comments@maximumpc.com

IFIXIT presents:

AUTOPSY

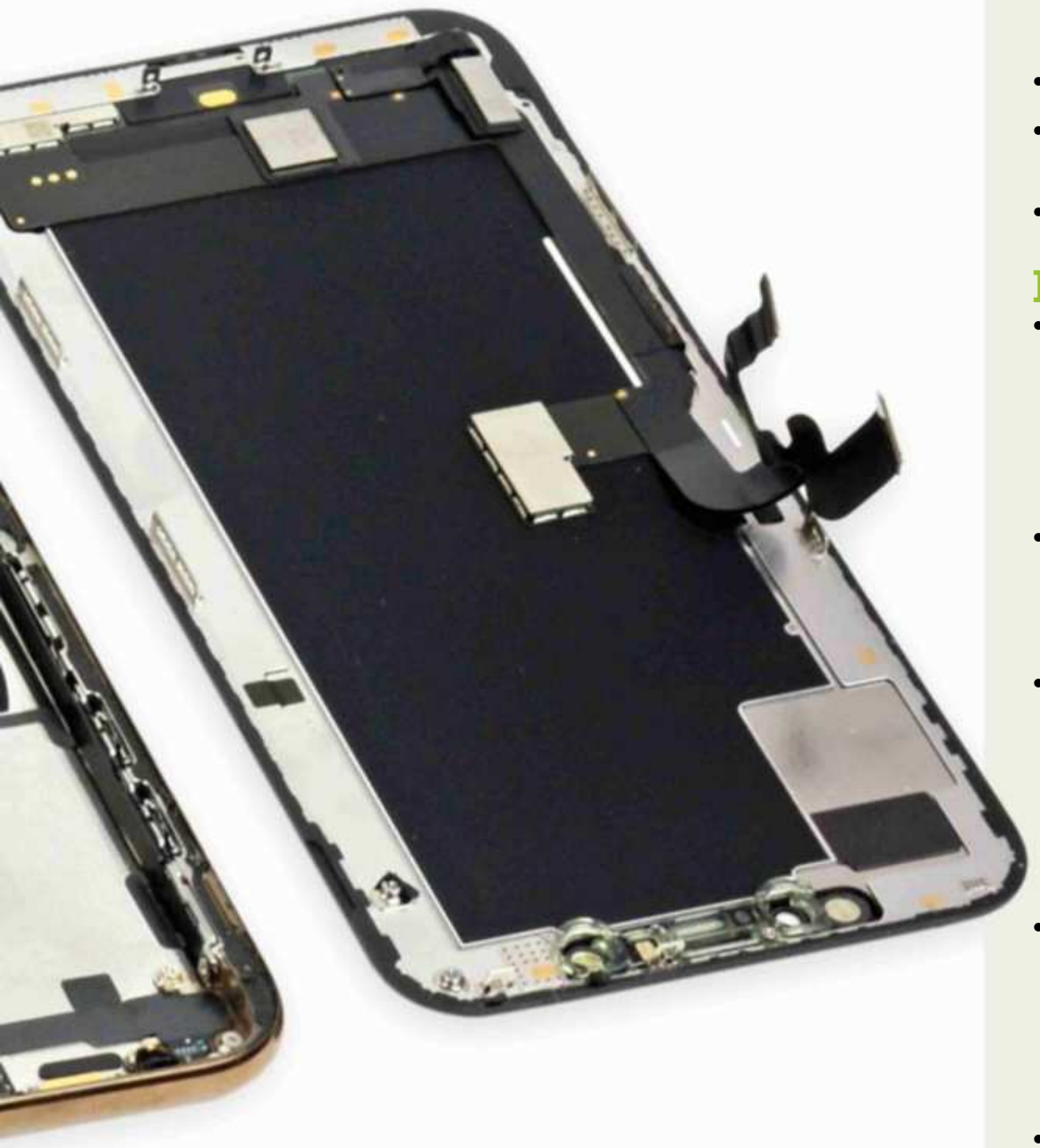
THIS MONTH WE DISSECT...

Apple iPhone XS

About iFixit

iFixit is a global community of tinkerers dedicated to helping people fix things through free online repair manuals and teardowns. iFixit believes that everyone has the right to maintain and repair their own products.
To learn more, visit www.ifixit.com.

Apple's Face ID technology makes another appearance.



You get into the new iPhones the same way you do the previous ones.

BACKGROUND

Last year's iPhone X had a weird name and the most advanced internals we'd ever seen. Now Apple turns it up to 11 with the iPhone XS and XS Max. We're taking apart the XS, so grab hold of your Roman numerals, and let's get started.

MAJOR TECH SPECS

- Hexa-core A12 Bionic SoC with a "next-gen" Neural Engine
- 5.8-inch (2436×1125) 458 ppi Super Retina OLED display with True Tone, wide color gamut, and 3D Touch
- 12MP rear cameras (wide-angle and telephoto) with f/1.8 and f/2.4 apertures and OIS, and 7MP selfie cam paired with TrueDepth Face ID hardware
- 64GB of onboard storage (256 and 512GB optional configs)
- Gigabit-class LTE (not 5G), as well as 802.11a/b/g/n/ac Wi-Fi, with MIMO, Bluetooth 5.0, and NFC
- Improved dust and water resistance with an IP68 rating

KEY FINDINGS

- Apple may be changing up its naming scheme, but we're glad it left the opening procedure alone. Our iOpener softens the hidden adhesive, then a suction handle and halberd spudger free the display. Though we feared Apple might use more adhesive to achieve that IP68 rating, we fared no worse than with ye olde IP67-rated predecessors.
- With the topside peripherals dispatched, we can turn our attention to the most important part of every S-series iPhone: the logic board. Having seen this kind of board before, we've got good at pulling this PCB sandwich apart.
- The S-year often comes with a camera upgrade, and Apple had a lot to say about these new sensors. The wide-angle sensor size has been increased by 32 percent, and pixel size has also been increased. One thing Apple forgot to mention about the new camera: All that 32 percent had to go somewhere, and the camera bump had to grow a little—your iPhone X case may not fit your iPhone XS.
- The XS packs a 10.13Wh battery (2,659mAh at 3.81V), weighing 39.5g—slightly downgraded from last year's X. But this decrease in capacity comes with a wild new battery configuration. Rather than using two cells to fill this L-shaped recess, Apple has constructed an all-new single-cell battery.
- What was revolutionary last year is quickly becoming standard—the XS comes with a sensor array for Apple's fancy Face ID tech. The Taptic engine and loudspeaker come out in an assembly, but easily separate.
- It looks like the rear glass is still sandwiched between the camera bump and the frame with dozens of tiny welds. Despite the many improvements, it's got the same iPhone 8/iPhone X back glass construction, meaning one tiny crack calls for a whole chassis replacement.
- Repairability score: 6 out of 10 (10 is easiest to repair). Critical display and battery repairs remain a priority in the iPhone. A display can be replaced without removing the Face ID hardware. Liberal use of screws is preferable to glue—but you need Apple-specific drivers (Pentalobe and tri-point) in addition to Phillips. Waterproofing complicates some repairs, but makes water damage less likely. Glass on front and back doubles the likelihood of drop damage—and if the back glass breaks, you'll be removing every component, and replacing the entire chassis.

Honeypot Role-Playing for the Raspberry Pi

YOU'LL NEED THIS

RASPBERRY PI
Model 2 or 3 is recommended.

OPENCANARY
Download the open-source app from https://github.com/thinkst/opencanary.

EARLY WARNING SYSTEMS provide alerts to pending issues, so immediate action can be taken to prevent or reduce further damage. "Honeypot" is a term assigned to a computer system designed to detect unauthorized access to the resources it makes available. Honeypots are configured to look like legitimate computer resources on a network; the computer can be posed to look like a fileserver containing data that would appeal to an attacker. A honeypot webserver, a honeypot database, or a honeypot application server would have resources staged as bait to attract the adversary. When the attacker tries to gain access to a specific resource, it is blocked, because the resource is fake. However, the attempt triggers an alert, and can be logged for analysis.

If an attacker has entered your network, depending on its configuration, it may be fairly easy for them to move around undetected. Using a simple Raspberry Pi, we can build a juicy-looking resource, which generates an alert revealing the attacker's presence when it detects them trying to access the system. The extensive list from the Awesome Honeypot resource (https://github.com/paralax/awesome-honeypots) details the multiple flavors of honeypots available. Let's install and test the open-source offering of OpenCanary (OC). **–SEAN CONWAY**

```
pi@picanary: ~
File  Edit  View  Search  Terminal  Help
(Not all processes could be identified, non-owned process info
 will not be shown, you would have to be root to see it all.)
Active Internet connections (only servers)
Proto Recv-Q Send-Q Local Address           Foreign Address         State       PID/Program name
tcp        0      0 0.0.0.0:ssh             0.0.0.0:*               LISTEN      -
tcp6       0      0 [::]:ssh                [::]:*                  LISTEN      -
udp        0      0 0.0.0.0:bootpc          0.0.0.0:*                           -
pi@picanary:~ $ netstat -plutn
(Not all processes could be identified, non-owned process info
 will not be shown, you would have to be root to see it all.)
Active Internet connections (only servers)
Proto Recv-Q Send-Q Local Address           Foreign Address         State       PID/Program name
tcp        0      0 0.0.0.0:22              0.0.0.0:*               LISTEN      -
tcp6       0      0 :::22                   :::*                    LISTEN      -
```

1 BASELINE BUILD

The bill of materials for this exercise is simple. Any version of Pi 2/3 hardware is acceptable. Even Pi Zero hardware with a wired or wireless network will work. The hardware required is minimal, because the device will be configured to simulate a service, not provide it. The operating system used in this project is 2018-03-13-raspbian-stretch-lite. The OpenCanary application software didn't have a version number, but can be downloaded from https://github.com/thinkst/opencanary.

›› A network-supported Pi 3 running Raspbian Stretch Lite was deployed for this project. Not all the software and application bells and whistles offered in the full Raspbian install are needed for this build. The project doesn't need a GUI, so there is no need to load the software. The Raspbian Lite version is acceptable for use in this project.

›› The configuration changes are done from the console command-line interface (CLI). The console is accessed using an SSH connection. The details to instantiate the Pi and establish the connection aren't covered here, but there's a number of resources that describe how to accomplish these prerequisites (www.raspberrypi.org/documentation/remote-access/ssh/).

›› This device will be hosting fake services. To ensure the device is secure, we are going to baseline what service ports are available, and then apply some service hardening. The CLI command `netstat -plutn` is an ideal command to remember for listing which service ports are available [**Image A**].

›› If you are not familiar with the naming convention for port services, drop the "n" from the command `netstat -plut`. This removes the port number to service lookup translation. Now you don't have to remember that SSH is port 22.

›› Start the exercise of baselining the system by issuing the `netstat` command to get an idea of what ports are currently open. When the services reconfiguration below is completed, run the command again to see the results of the cleanup:

```
sudo service --status-all
sudo systemctl disable avahi-daemon
sudo systemctl disable bluetooth
sudo systemctl service rsync disable
sudo systemctl disable motion
```

›› Retain this port knowledge as the baseline for the system. Any port additions that appear in the list from this point forward are a result of something changing. When making software changes, it is best practice to do a port check to confirm nothing has been added as a result of the change. Because this honeypot is being

configured as bait, we don't want to leave any ports exposed that we don't want to make available.

2 CAGING THE CANARY

Let's add some software prerequisites for the OC installation. Countless times, software installs fail due to local repository content being stale. It is best practice—or let's just say it will save you some headaches—if you make it a habit to perform a software update before any software additions.

```
sudo apt-get update
sudo apt-get install git python-virtualenv python-pip python-dev libssl-dev libffi-dev samba
```

» Not all the Potemkin village (a construction, literal or figurative, built solely to deceive others into thinking that a situation is better than it really is) built of the services supported through OC is available in the application. Samba, for example, must be fully installed and set to "autostart" for it to be used by OC. The Samba configuration file provided in the OC installation must be installed in Samba to enable the service.

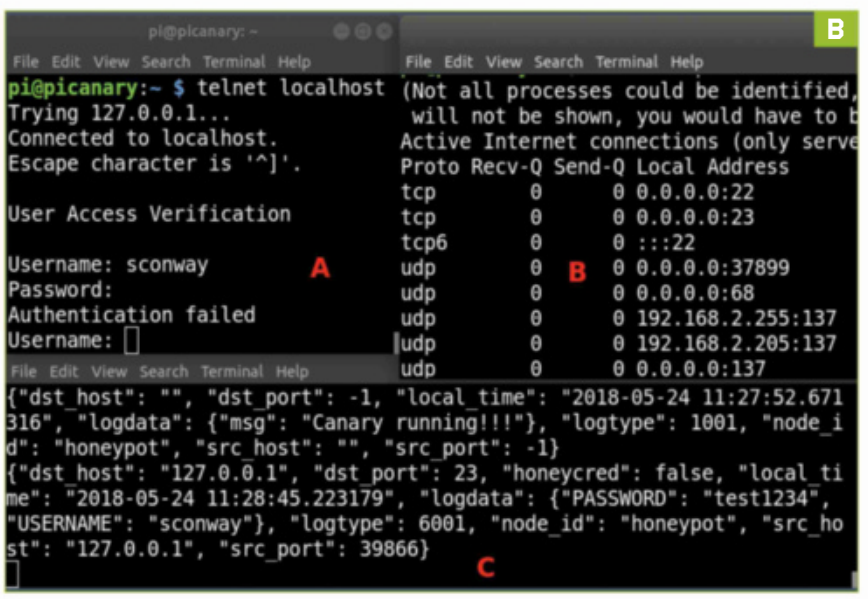
» The documentation indicates that OC is to be installed in a Python virtual environment. Some systems require different versions of the same software library. The separation provided by virtual environments makes managing multiple software libraries easier. Creating the honeypot in a virtual environment enables the device to keep the honeypot service separate from other services. However, trying to use a honeypot to provide additional services should raise security concerns, if you think about it. We won't argue with the design to use a virtual environment. Create the Python environment, then enter (or source) the environment. Clone the Github software installation directory, change to the directory, and start the OC installation:

```
virtualenv -p python2 canary-env
source ./canary-env/bin/activate
git clone https://github.com/thinkst/opencanary
cd opencanary/
python setup.py install
```

» OC ships with a default configuration file. The installation docs indicate the `opencanaryd –copyconfig` command can be used to position the configuration file correctly in order for the app to start. The command failed to work. Reading the error message displayed on the screen, and a quick cull of Internet search results, suggested copying the OC configuration file to the proper location manually to establish a working config file:

```
sudo mkdir /etc/opencanaryd
sudo cp ~/opencanary/opencanary/data/settings.json /etc/opencanaryd/opencanary.conf
```

» Before giving in to the immediate impulse to issue the command to start the application, let's make some OC


B
pi@picanary: ~
File Edit View Search Terminal Help
pi@picanary:~ $ telnet localhost
Trying 127.0.0.1...
Connected to localhost.
Escape character is '^]'.
User Access Verification
Username: sconway
Password:
Authentication failed
Username:
A
File Edit View Search Terminal Help
(Not all processes could be identified,
will not be shown, you would have to t
Active Internet connections (only serve
Proto Recv-Q Send-Q Local Address
tcp 0 0 0.0.0.0:22
tcp 0 0 0.0.0.0:23
tcp6 0 0 :::22
udp 0 0 0.0.0.0:37899
udp 0 0 0.0.0.0:68
udp 0 0 192.168.2.255:137
udp 0 0 192.168.2.205:137
udp 0 0 0.0.0.0:137
B
File Edit View Search Terminal Help
{"dst_host": "", "dst_port": -1, "local_time": "2018-05-24 11:27:52.671316", "logdata": {"msg": "Canary running!!!"}, "logtype": 1001, "node_id": "honeypot", "src_host": "", "src_port": -1}
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C

CANARIES IN A COAL MINE

Canaries were used in mines as early warning systems to detect dangerous gases, such as carbon monoxide. Miners took caged canaries into the tunnels with them. If the gas in a mine reached a level where it impacted the canary, the miners knew they were at risk, too, and would attempt to leave. Top fact: The canaries usually revived. We know someone who has an RV trailer at a permanent camp site. Each year, when she closes the trailer for the winter, she places a few peanuts in strategic locations. In the spring, when she returns to open the trailer, if the peanuts are gone, she knows there were rodents in the trailer—another handy early warning system, triggering a whole other level of cleaning.

configuration changes, to give us an idea of what OC is actually starting. Using your favorite text editor, modify the "/etc/opencanaryd/opencanary.conf" file. Replace all `true` values with `false`, with the exception of `"telnet.enabled": true, 23`. This `true` value leaves us one service for testing. Be extra careful when modifying the contents of this configuration file; syntax errors cause a failure in the startup of the OC application.

» A main page call from the CLI for `opencanaryd` provides a list of the operations the command supports. The `start` options worked from the CLI, and gave the appearance of working (the log files indicated that the application started) when used in the autostart configuration. The impression was different from what was actually happening. The OC application went into a loop of continuous restarts when the `start` option was used. The `stop` option appeared to have worked from the CLI. As mentioned, `–copyconfig` didn't deliver what it promised. Proven through testing, the following command was used to fire up the application:

```
opencanaryd --dev
```

» The application generates output to the screen, eventually reaching stasis. Recall that the OC configuration was modified to initiate one service: Telnet. The following lines appear in the text outputted to screen: `Added service from class Telnet in opencanary.modules.telnet to fake.... ServerFactory starting on 23,` as an indication OC is now supporting telnet.

» Open a second console window to the OC device. Then issue the `netstat` command flavored `-plutn` to check which ports are open—see annotation "B" [Image B]. TCP port 23 should have taken residence in your port scan. Recall that we installed the Samba after we baselined the open ports. That installation added port 137, shown in the screenshot. To test the configuration, initiate a Telnet session from a separate host machine to the OpenCanary device (annotation "A"). Login fails, but each attempt generates output from OpenCanary (annotation "C").

3 CONFIGURING EMAIL ALERTS

Return to the screen that is outputting the log information, and press Ctrl–C to stop the OC

```
    "logger": {
        "class": "PyLogger",
        "kwargs": {
            "formatters": {
                "plain": {
                    "format": "%(message)s"
                }
            },
            "handlers": {
                "SMTP": {
                    "class": "logging.handlers.SMTPHandler",
                    "mailhost": ["authenticated.mail.server", 25],
                    "fromaddr": "canary@yourdomain.com",
                    "toaddrs" : ["youraddress@yourdomain.com"],
                    "subject" : "OpenCanary Alert",
                    "credentials" : ["myusername", "password1"]
                },

Authors values
            "SMTP": {
                "class": "logging.handlers.SMTPHandler",
                "mailhost": ["[redacted]", 587],
                "secure": [],
                "fromaddr": "[redacted]",
                "toaddrs" : ["[redacted]"],
                "subject" : "OpenCanary Alert",
                "credentials" : ["[redacted]", "[redacted]"]
            },
```

C

application, and return a CLI prompt. Now open the working "opencanary.conf," and make the following changes to have the alert messages sent to an email account.

›› Insert the mail configuration details into the script using the screenshot above [**Image C**] to determine where the information should be positioned in the file. Remember: Syntax errors cause an OC startup to fail.

```
"SMTP": {
 "class": "logging.handlers.SMTPHandler",
"mailhost": ["authenticated.mail.server", 25],
"fromaddr": "canary@yourdomain.com",
"toaddrs" : ["youraddress@yourdomain.com"],
"subject" : "OpenCanary Alert",
"credentials" : ["myusername", "password1"]
},
```

›› You need to substitute the email configuration values from your provider with the placeholder values in the configuration. Email providers may make these details available on their website or in documentation. Without accurate mail server setting, establishing email support in OC is near impossible.

›› Port 25, shown in the script, is the standard port value for the SMTP protocol. Do not assume your provider uses this value. In addition, the email configuration provided from the OC site and in the documentation doesn't reflect secure mail services. We've provided the secret sauce (the attribute to support secure mail services) required in the OC configuration in order for the service to function. The values used in our configuration are grayed-out, but the secret-sauce text dependencies are there.

›› Fire up the OC application again, and the email account defined in the configuration should receive messages. Once email is confirmed to be working, disable email alerts. With all the services OC supports enabled, 12 email messages are delivered as part of the startup. To avoid the message rush, it is recommended that email support be disabled during development.

4 ADD A LITTLE SAMBA

The Samba OpenCanary module monitors a log file produced by the Samba full_audit VFS module. The process to have OpenCanary support Samba has more overhead than we have encountered for services so far. OpenCanary requires Samba to be installed and functioning on startup. The Samba app must be configured to have its events written to "syslog LOCAL7." The syslogger application must be configured to log to the "/var/log/samba-audit.log" file.

›› Let's preserve the default configuration file for the Samba install in the Samba configuration directory, by making a backup before copying the Samba configuration file "smb.conf."

```
cp /etc/samba/smb.conf /etc/samba/smb.conf.bak
```

›› The default Samba configuration file is wonderfully documented; the OC Samba configuration file not so much. The OC file only contains the needed configuration details, and no supporting commentary.

›› The "smb.conf" file enables Samba to distribute specific information. The purpose of this configuration detail is to make Samba a part of the Potemkin village. If you modify the file's contents, avoid providing details that can help the bad guys uncover the ruse. Using a server string such as "SAMBACANARY" is less than ideal if you are trying not to disclose the server's true purpose.

›› Using your favorite text editor, create the file "/etc/rsyslog.d/samba.rsyslog.conf" containing the following configuration entries on separate lines:

```
$FileCreateMode 0644
local7.*        /var/log/samba-audit.log
```

this establishes syslog support for samba.

5 WRAP UP TESTING

For this final round of testing, let's expand the OC configuration to enable all services supported by OpenCanary, including Samba. Using a text editor, modify the working "opencanary.conf" file to replace all the `false` values with `true`. In addition, restore the configuration that provided email support in the application. We are now ready to test. Stop and start the OC application to establish the OC configuration.

›› Run the `netstat` command replacement `ss` to discover the service ports supported by OC when configured. There should be a raft of ports available.

```
Service/port(s)
"ftp.enabled": 21
```

D

OpenCanary Alert 28 May, 2018 15:58

From: [redacted]

To: [redacted]

A

```
{"dst_host": "192.168.2.205", "dst_port": 445, "local_time": "2018-05-28 20:58:17.116835", "logdata":
{"AUDITACTION": "pread", "DOMAIN": "SRVSTORAGE", "FILENAME": "2018_finance.txt", "LOCALNAME": "srvstorage",
"REMOTENAME": "desktop-ne9fdct", "SHARENAME": "myshare", "SMBARCH": "Vista", "SMBVER": "SMB3_11", "STATUS": "ok",
"USER": "sconway"}, "logtype": 5000, "node_id": "honeypot", "src_host": "192.168.2.209", "src_port": "-1"}
```

B

```
May 28 15:58:17 picanary smbd_audit: sconway|192.168.2.209|192.168.2.205|desktop-
ne9fdct|myshare|srvstorage|SMB3_11|Vista|2018/05/28 15:58:17|SRVSTORAGE|pread|ok|
2018_finance.txt
```

```
"http.enabled": 80
"smb.enabled": 137, 138, 139, 445
"mysql.enabled": 3306
"ssh.enabled": 8022
"rdp.enabled":
"sip.enabled": 5060
"snmp.enabled":
"ntp.enabled":123
"tftp.enabled": 69
"telnet.enabled": 23
"mssql.enabled": 1433
"vnc.enabled": 5900
```

» Scapy and Pcapy are two additional software installs found in the OC support pages. Few details are provided on what they are required for. We speculate that they may be part of the additional configuration work required to enable rdp and snmp, similar to establishing Samba support in OC.

» From an external computer, access the file shared by Samba. If the OC configuration is correct, an email message, marked "A" [**Image D**], is sent, which can be correlated to the message in the Samba audit log, marked "B."

» The other services can be tested by trying to access them using normal tools to make connections. A MySQL connection call or a TFTP request should be enough to generate an alert. Of course, if this device was going to be deployed in a production environment, the documentation would include all the confirmation tests we've conducted, to determine whether the honeypot we have created is providing the services required.

» Let's expand the testing by using the Nmap: Network Mapper tool on a separate host machine, and have it examine the OpenCanary device [**Image E**]. Nmap is an open-source tool for examining networks. It is simple (belly laugh) to use and is ideal for security auditing—it's simple in the sense of providing a command to generate results; extrapolating those results is a whole other exercise.

» Nmap can be used to determine which hosts are available on the network, which services those hosts are offering, which operating systems (and OS versions) they are running, what type of packet filters/firewalls are in use, and more.

» We can't say we recognize the "oa-system" service shown in the screenshot. A check of the OC configuration shows this was established as an alternate SSH service, because port 22 was in service providing SSH support to deliver the console.

» If this was a production OpenCanary implementation, having port 22 and port 8022 being supported on a device sends up red flares, raising questions to those sniffing around. It might be more prudent to enable SSH support to the serial port on the device through a terminal server, make port 22 available as a fake SSH offering, and remove the obscure port 8022 reference to make the device appear more normal. Honeypot design considerations are beyond the scope of this article, however.

E

```
sconway@ubuntu17: ~
File  Edit  View  Search  Terminal  Help
sconway@ubuntu17:~$ sudo nmap -sT 192.168.2.205

Starting Nmap 7.60 ( https://nmap.org ) at 2018-05-31 07:33 CDT
Nmap scan report for 192.168.2.205
Host is up (0.0044s latency).
Not shown: 990 closed ports
PORT     STATE SERVICE
21/tcp   open  ftp
22/tcp   open  ssh
23/tcp   open  telnet
80/tcp   open  http
139/tcp  open  netbios-ssn
445/tcp  open  microsoft-ds
1433/tcp open  ms-sql-s
3306/tcp open  mysql
5900/tcp open  vnc
8022/tcp open  oa-system
MAC Address: B8:27:EB:29:A3:FD (Raspberry Pi Foundation)

Nmap done: 1 IP address (1 host up) scanned in 13.37 seconds
sconway@ubuntu17:~$
```

THE EVOLUTION OF THE HONEYPOT

Honeypots have evolved from the defunct Nepenthes through its replacement, Dionaea (https://dionaea.readthedocs.io). The resource information provided on the Github link (https://github.com/paralax/awesome-honeypots#honeyd) is testament to the evolution of the tech, and what it's capable of providing.

With the evolution of honeypots (collectors), a need for management and logging of the data became important. Modern Honey Network (MHN) (https://github.com/threatstream/mhn) is a centralized server, for deploying collectors, gathering their data, and providing a web interface for management.

In 2001, the Internet Storm Center (ISC) was created following the detection, analysis, and widespread warning of the Li0n worm. The ISC provides warning services and works to combat malicious attackers by supporting a distributed detection system called DShield (https://secure.dshield.org/about.html). DShield collects data about malicious activity from across the Internet. The service is free, sponsored by the SANS Institute for the benefit of all Internet users. The public can register to share data from their firewalls or intrusion detection systems. Registration is encouraged, but not required. The data is cataloged and summarized, and can be used to discover trends in activity, confirm attacks, or assist in making better firewall rules.

» Try the command `sudo nmap -A` with the IP address of the device to have Nmap do some operating system analysis. Don't be surprised if the command takes a few minutes to produce results—it is probing all the ports discovered, and trying to determine information about the service. The output is pretty extensive, so in the interest of space, it has been omitted here.

6 THIS IS A DEAD CANARY

One of the limitations of OpenCanary is that it doesn't generate any alerts from the poking and prodding done through Nmap. If you think about it, that might be a limitation to consider if you are deploying a honeypot. If there is a bad guy in your network, one of his reconnaissance tools will be Nmap. It would be ideal if the honeypot alerted you to the scans done by Nmap, because this is not normal activity on your network.

» There you have it, folks: OpenCanary configured on a Raspberry Pi, sending alerts to an email address. There are companies offering honeypot services using Pis. You now have an inside scope on the open-source version of one product. Hopefully, this tutorial gives you some idea of the technology and design considerations needed if you had thoughts of deploying such devices. Glad we could help!

Protect Your Identity with the VPiN

YOU'LL NEED THIS

RASPBERRY PI
This credit-card sized computer costs around $35.

VPN SUBSCRIPTION
We're using the Nord VPN service in this tutorial.

CARING ABOUT YOUR ONLINE PRIVACY and actually following best practices to protect it are two different things. As a *Maximum PC* reader, it's likely that you know the principles of what you should do to avoid the great data collectors and geo-locators in the sky, but maintaining constant vigilance is an effort that soon gets tiresome, if not downright impossible.

For example, you know that you should be using a VPN to avoid any ISP-level filters. Setting up and using a log-free VPN service from your desktop is straightforward enough, but what about all the other devices you have in your home? For example, if you use a games console to watch Netflix or YouTube on your TV, how do you route traffic from there effectively? No consoles have built-in VPN software. There's no app in the PlayStation store.

One solution, of course, would be to buy a router that can connect directly to a VPN service, protecting all the traffic that travels around your home network at a single stroke. Or, if you have an older router, you could modify it with OpenWRT firmware, and add controls such as these in. Or, if you want a cheaper and more straightforward solution, you could always use a Raspberry Pi.... **–ADAM OXFORD**

1 PI RIGHT THERE

With just a few fairly simple scripts, you can configure any Raspberry Pi to be a headless VPN gateway. This means that when it's connected to your router, you can send traffic to it from other devices before they connect to the outside world—essentially putting them behind a VPN [**Image A**]. Here, we're using a first-generation Pi—it's a nifty repurposing of a piece of gear that's past its sell-by date for most other common Pi-related projects.

» To get started, you need four things: a Raspberry Pi, an SD card preloaded with the Raspbian operating system, and a subscription to a VPN service of your choice. We're going to use Nord VPN, which assures us that it doesn't log user behavior or filter for particular activities, such as P2P protocols. There are services that promise even more anonymity, or are more affordable, but Nord is a good place to start investigating options.

» The fourth thing you need is a copy of your provider's OpenVPN configuration files and encryption certificates. There are usually a lot of these—one for each server you can connect to—so pick a handful that you want to be able to quickly access. We opted for two US and two UK servers, choosing one that supports the UDP protocol and one that supports TCP/IP.

» You should find these configuration files on your VPN provider's website. Download them, then unzip them into a folder on your desktop.

2 INSTALL PACKAGES

We want our Pi to run headless; in other words, without a keyboard and monitor attached, which means that once it's up and running, we'll need to access it using a remote shell and SSH. For the first run, it can be easier to access the Pi directly by plugging in peripherals, at least until you've made sure it has a fixed IP address on your network—essential for this project.

» To do that, open a terminal on the Pi desktop, and type `sudo nano /etc/network/interfaces`. Edit this file to look like this (you can choose any free IP address for the line that ends in "12"; bear in mind that the "1" in the third part of the address could be another number):

```
auto lo
iface lo inet loopback

auto eth0
allow-hotplug eth0
iface eth0 inet static
   address 192.168.1.12
   netmask 255.255.255.0
   gateway 192.168.1.1
   dns-nameservers 1.1.1.1 1.0.0.1
```

» Press Ctrl-O to write out the file, and then press Ctrl-X to quit Nano.

```
studiopc@studiopc:~$ ssh pi@192.168.1.160
pi@192.168.1.160's password:

The programs included with the Debian GNU/Linux system are free software;
the exact distribution terms for each program are described in the
individual files in /usr/share/doc/*/copyright.

Debian GNU/Linux comes with ABSOLUTELY NO WARRANTY, to the extent
permitted by applicable law.
Last login: Tue Aug  7 16:32:43 2018 from 192.168.1.59
pi@raspberrypi:~ $ nano uk.sh
pi@raspberrypi:~ $ sudo ./uk.sh
openvpn: no process found
pi@raspberrypi:~ $ Tue Aug  7 16:34:32 2018 OpenVPN 2.3.4 arm-unknown-linux-gnueabihf [SSL (OpenSSL)] [LZO] [EPOLL] [PKCS11] [MH] [IPv6] built on Jun 27 2017
Tue Aug  7 16:34:32 2018 library versions: OpenSSL 1.0.1t  3 May 2016, LZO 2.08
Tue Aug  7 16:34:32 2018 WARNING: file '/etc/openvpn/vpncred.txt' is group or others accessible
Tue Aug  7 16:34:32 2018 WARNING: --ping should normally be used with --ping-restart or --ping-exit
Tue Aug  7 16:34:32 2018 Control Channel Authentication: tls-auth using INLINE static key file
Tue Aug  7 16:34:32 2018 Outgoing Control Channel Authentication: Using 512 bit message hash 'SHA512' for HMAC authentication
Tue Aug  7 16:34:32 2018 Incoming Control Channel Authentication: Using 512 bit message hash 'SHA512' for HMAC authentication
```

A

›› Now turn the Pi off, and remove all peripherals, leaving just the networking cable in place. Then reconnect the power supply to get it started again.

›› Once the Pi has booted up, you should be able to access it from another PC using SSH. In our case, the command to connect is `ssh pi@192.168.112` and the password is the default, "raspberry." You'll probably want to change the password.

›› The next thing you need to do is install the OpenVPN packages with the following command:

```
sudo install openvpn.
```

›› Next, navigate to the folder where you need to keep your OpenVPN configuration files by typing `cd /etc/openvpn`. You need to download the configuration files from your VPN provider. In our case, we can do this using `wget`—don't forget to use `sudo` because the "etc/" folder isn't writable by ordinary users. In our case, the command is `sudo wget https://downloads.nordcdn.com/configs/archives/servers/ovpn.zip` followed by `sudo unzip ovpn.zip` to decompress it.

›› A quick `ls` command shows if you have been successful. There should be a list of files ending in ".ovpn." Note that some VPN providers may have packaged these files with subdirectories, as an example for connections encrypted with optional 128 or 256-bit protection. You need to move the files to the "etc/openvpn" directory using the `mv` command.

›› You can now open a connection to any of these servers using the command `sudo openvpn example.ovpn –daemon`, where `example` is the filename of the configuration file.

›› If you try this now, you'll notice that the script asks for your username and password to authenticate the connection. Do test to see if the connection is working by typing `ifconfig`. You should see a connection marked "TUN," which is your VPN tunnel.

3 YOU SHALL NOT PASSWORD!

So far, we have a slightly cumbersome way of connecting our Pi to a VPN via a terminal that requires you to enter your username and password when you want to connect. Good, but it could be better—we're going to create a few scripts to automatically create your credentials.

›› Take a look at the VPN files you downloaded to your desktop and open one of them. You should see that it starts the client and that there's a list of commands. These include a line that contains `auth-user-pass`. We can alter this line to automatically feed a username and password to our config file when it is called.

›› Back in your SSH connection to the Pi, navigate back to "/etc/openvpn," and type `sudo nano vpnlogin`. This should open up the Nano text editor. Create a text document that has nothing except your username for the VPN provider on the first line, and your password on the second. Hit Ctrl-O to write the contents to disk, then Ctrl-X to quit Nano.

›› Once you've done that, pick the VPN connection you think you'll use the most, and edit the config file using `sudo nano example.ovpn`. Change the line that says `auth-user-pass` to `auth-user-pass vpnlogin`.

›› Now when you start that connection using the `openvpn` command, it should connect directly without the password prompt. (See boxout below to change all the config files at once.)

›› So far so good, but we don't want to have to type a long command every time we need to connect to a VPN. Remember taking a note of your most likely used servers right back at the start? Good, because we're going to create a quick script that will enable you to start and switch between those with a simple command.

›› It begins with an instruction to close any open VPN connections, then starts the OpenVPN daemon, filling in the credentials from the text file we just created.

›› Back in your home folder, type `nano vpn1.sh`:

```
#!/bin/bash
sudo killall openvpn
sudo -b openvpn /etc/openvpn/example.ovpn
```

›› Repeat this step for the three or four VPN connections you think you'll use the most, adding one to the number in the filename. Now you can start or switch your connection by SSHing into the Pi from any computer on the network, and typing `sudo ./vpn1.sh`.

›› Finally, to route traffic via the Pi, you need to go back to your PlayStation (or other device), and change the Internet settings [**Image B**]. Leave everything in its default setting apart from the Gateway and DNS servers.

›› Change Gateway to the IP address of your Pi, and set the DNS server to 1.1.1.1, 8.1.1.8.

›› And that's it. Now you can make your PS4 appear in another country without leaving your living room.

ONE BIG EDIT FOR MAN

Remember that line in the VPN configuration file for `auth-user-pass`? We need to change that so that the credentials file we just created is called automatically. This means that you need to change that line to:

```
auth-user-pass vpnlogin
```

You can do that manually for the three or four servers that you think you'll use the most, and then just set up scripts to start those servers whenever you need them. But what if you want to pretend you're in Sweden for a day, or South Africa? Can you even remember what the VPN password was?

Nord VPN supplies over 2,000 different config files—one for each server, with both TCP and UDP protocols. To edit all those files at once, open up an SSH connection to your Pi, and navigate to "etc/openvpn" again. Now run the following command to use SED for a batch edit of all the .ovpn files:

```
find . -type f -name \*.ovpn -exec sed -i.bak 's|auth-user-pass|auth-user-pass vpnlogin|g' {} +
```

This has the added benefit of also creating a backup of the existing files.

Master Chrome's Malware Tool

YOU'LL NEED THIS

CHROME
Google's browser comes with a built-in malware scanner.

MANY OF US HAVE GOOGLE CHROME running on our PCs. While Microsoft Edge is a very good web browser, Chrome is the best option if you regularly use Google websites and services. But did you know that Chrome can also scan your PC for malware? While malware can infect your PC more widely, it often causes problems with your browser, such as changing your homepage or search engine without your permission, or perhaps you keep being redirected to sites you don't want to visit. That's where Chrome's built-in malware scanner comes in, and we'll show you how to use it right here. It's actually a fairly new tool, and Google worked with security firm ESET to develop the technology. A word of warning: It isn't designed to be a complete security guard for your PC; that's the job of Windows Defender, which is installed by default on Windows 8, 8.1, and 10. –**DAN GRABHAM**

1 START CHROME—IF YOU CAN

If you're thinking about scanning for malware, chances are you're either checking that your computer doesn't have any issues that you don't even know about, or looking to resolve a problem that you've discovered already. Hopefully, you haven't got a big issue with your PC that prevents you from starting Chrome [**Image A**] in the first place, such as aggressive pop-ups. If you have, try scanning your PC with Windows Defender or a third-party antivirus/security suite.

2 ACCESS CHROME'S SETTINGS

Click the three dots to the right of the address bar to go to Google Chrome's main menu, then click the "Settings" option. Another way to access the same option is to type "chrome://settings" into the address bar. Once in Settings, scroll down to the bottom of the window, and click "Advanced" [**Image B**]. This will show you additional settings, including the one we need.

3 FIND THE OPTION

Again, you need to scroll right down to the bottom of the page that opens—this is where more complex features of Google Chrome are available, covering things such as printing and hardware acceleration. You should now see a panel called "Reset and clean up" (we'll come to "Restore settings to their original defaults" shortly). What we're interested in for our current purposes is the "Clean up computer" option [**Image C**], so click that to get started.

4 CLEAN UP YOUR COMPUTER

This simple page enables you to "Find and remove harmful software" [**Image D**], and it also gives you the option to share this information with Google, including details about your system and its settings, as well as any malware (if any) contained on it. Generally speaking, the information you share is used by Google to improve the software in the future. You can also access this page by typing "chrome://settings/cleanup" in Chrome's address bar.

5 SCAN IN PROGRESS

Now click the "Find" button—it's the blue text on the right of the previous screen; it's not that obvious a button, but Chrome matches Google's styling cues, rather than those of Windows these days. You should then see a somewhat blank-looking screen as Google scans your PC for harmful software [**Image E**]. It will only take a few minutes if you have a reasonably new PC, but it will take longer if your PC is getting a little long in the tooth, or contains a lot of files and apps.

6 NOTHING FOUND

Most people then see a screen that announces that no harmful software has been detected on their PC [**Image F**]. Well done if you see this, because it means your PC is clean, and you're probably very good at not clicking the wrong stuff—such as fishy email attachments, to name but one example. Now you are free to just browse to another webpage in the same tab, or close Chrome completely by closing the tab if you don't need to do anything else online.

7 BUT IF THERE'S A PROBLEM...

If you haven't been so lucky, you will see one of two messages [**Image G**]. The main one is the bottom message, which is Chrome offering to remove harmful software. Click "Remove," then as soon as it's done, we recommend running a scan with Windows Defender or a third-party antivirus suite. You might also be asked if you want to restore Chrome's search engine option back to its default.

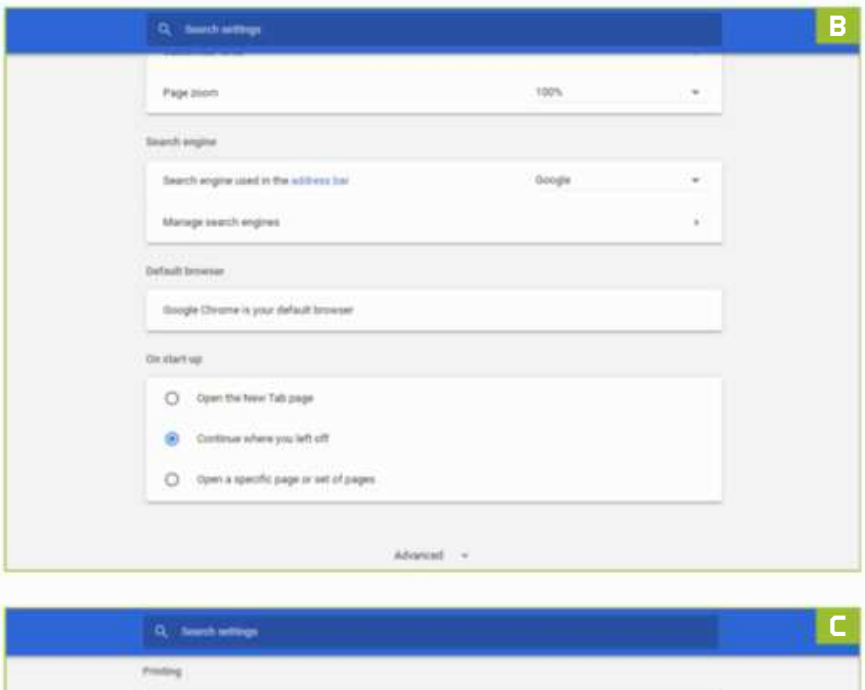
8 RESET SETTINGS

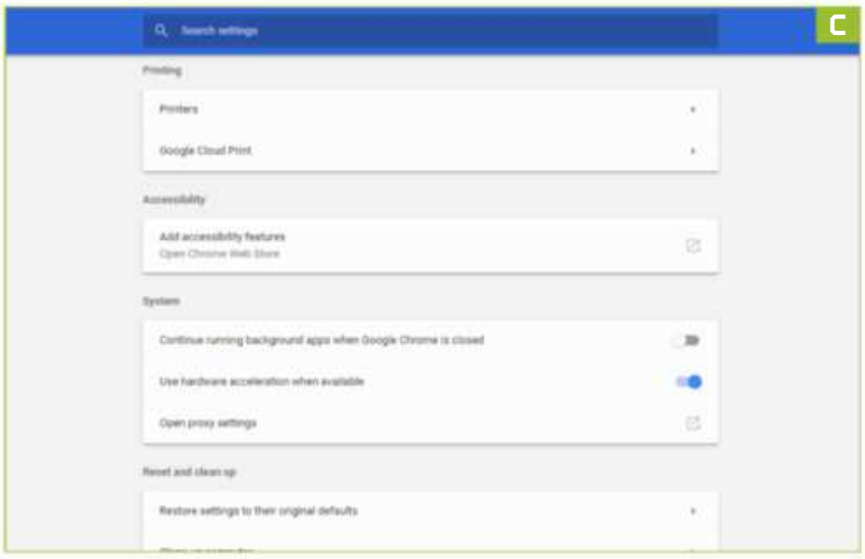
Remember that "Restore settings to their original defaults" option we mentioned [**Image H**]? We recommend doing that if you're still having issues with Chrome, even after the malware sweep. Note that doing so clears your cookies and extensions, as well as your browser settings, and homepage. It doesn't remove any of your bookmarks, history, or saved passwords, though, so you're safe there.

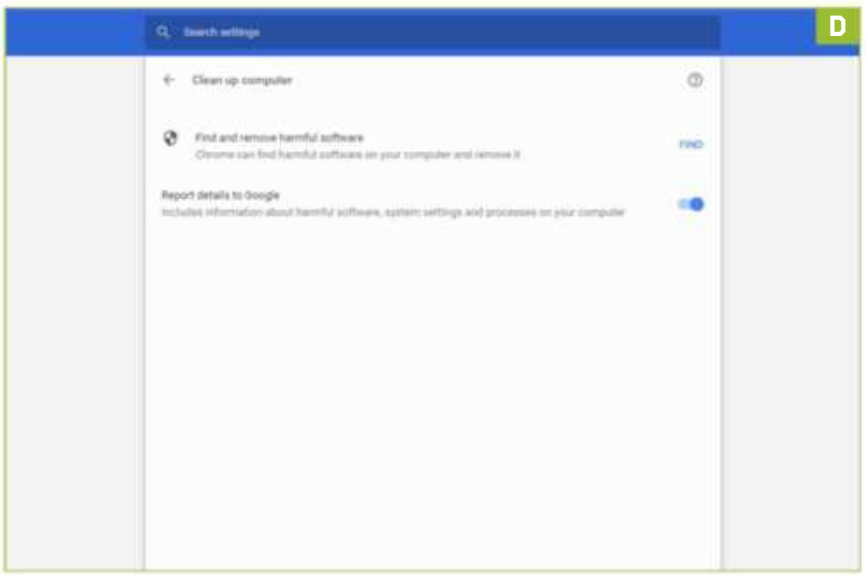
OLDER WINDOWS?

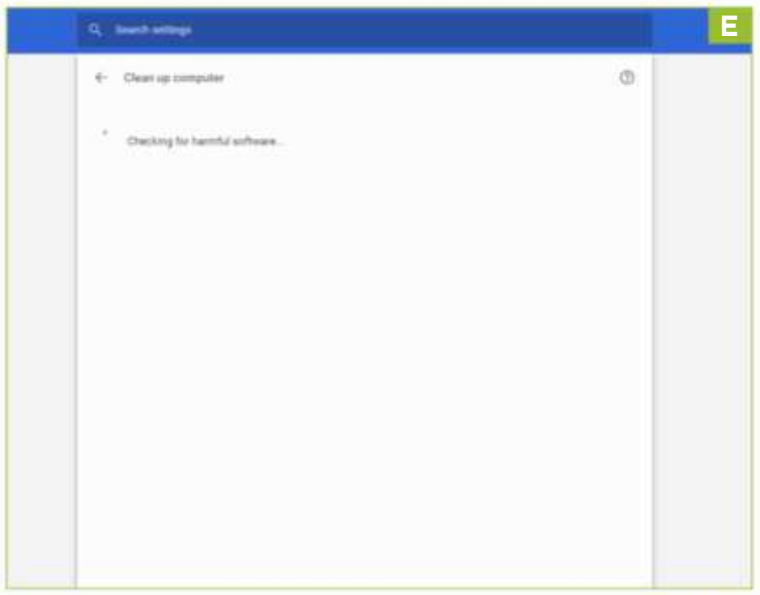
Are you still running Windows 7 or Vista? Then we recommend you download Microsoft Security Essentials from http://bit.ly/msftseces.

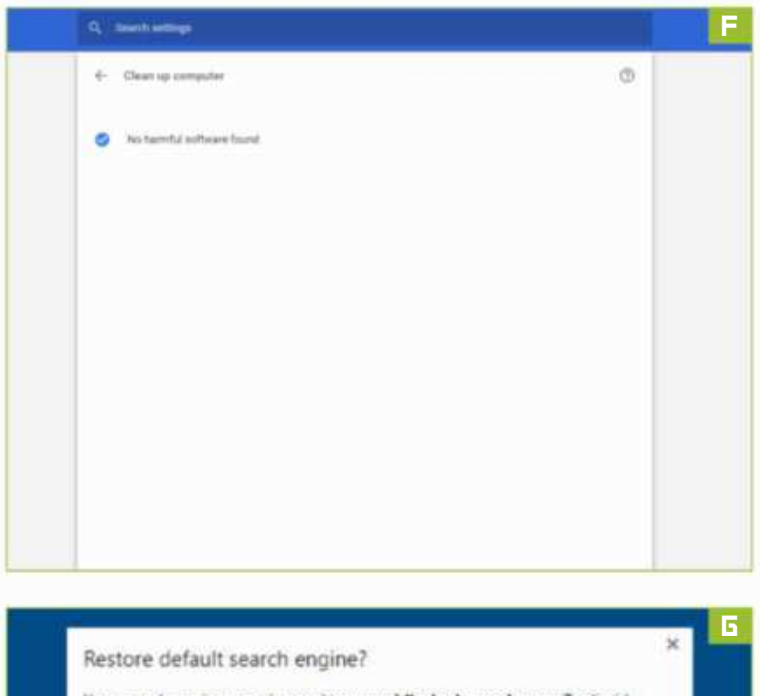
A
Google

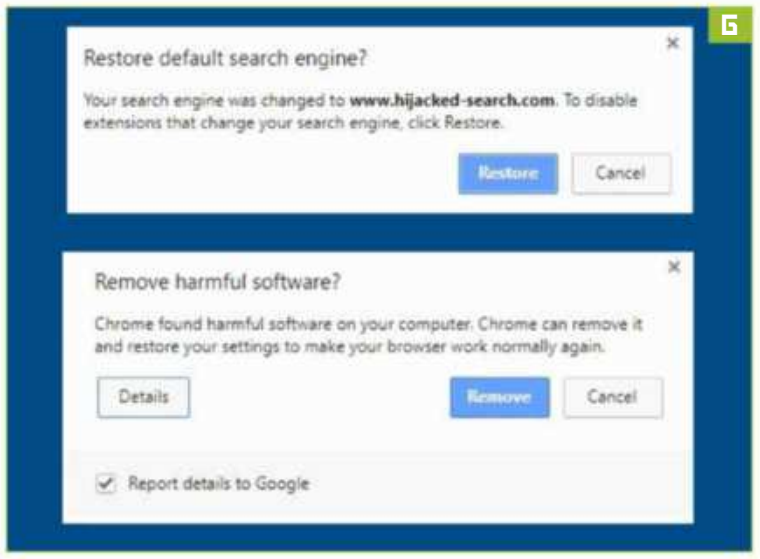

B
Search settings
Page zoom
100%
Search engine
Search engine used in the address bar
Google
Manage search engines
Default browser
Google Chrome is your default browser
On start up
Open the New Tab page
Continue where you left off
Open a specific page or set of pages
Advanced

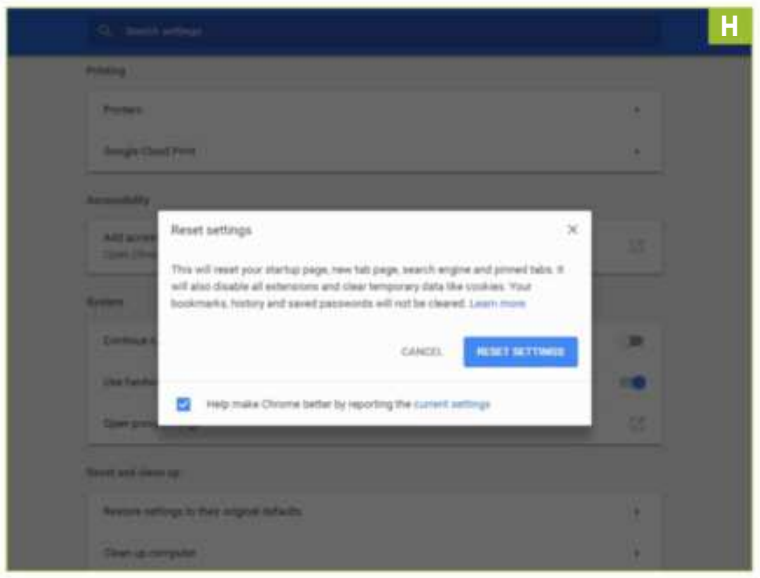

C
Search settings
Printing
Printers
Google Cloud Print
Accessibility
Add accessibility features
Open Chrome Web Store
System
Continue running background apps when Google Chrome is closed
Use hardware acceleration when available
Open proxy settings
Reset and clean up
Restore settings to their original defaults


D
Search settings
Clean up computer
Find and remove harmful software
Chrome can find harmful software on your computer and remove it
FIND
Report details to Google
Includes information about harmful software, system settings and processes on your computer


E
Search settings
Clean up computer
Checking for harmful software...


F
Search settings
Clean up computer
No harmful software found


G
Restore default search engine?
Your search engine was changed to www.hijacked-search.com. To disable extensions that change your search engine, click Restore.
Restore
Cancel
Remove harmful software?
Chrome found harmful software on your computer. Chrome can remove it and restore your settings to make your browser work normally again.
Details
Remove
Cancel
Report details to Google


H
Reset settings
This will reset your startup page, new tab page, search engine and pinned tabs. It will also disable all extensions and clear temporary data like cookies. Your bookmarks, history and saved passwords will not be cleared. Learn more
CANCEL
RESET SETTINGS
Help make Chrome better by reporting the current settings

Create a Pop-Art Portrait in Photoshop

YOU'LL NEED THIS

PHOTOSHOP
Subscribe to a suitable package at www.adobe.com.

POP ART WAS A CREATIVE MOVEMENT that began in the late 1950s and flourished in the United States. It saw the artistic space that had been previously inhabited by refined painting and sculpture invaded by common objects, particularly comic-book panels and mundane images, such as Andy Warhol's soup cans.

There was more to pop art than a few stacked tins, however—it also saw the removal of subjects from their contexts, and a return to hard-edged composition in contrast to the softness of earlier portraiture. It could be surreal, minimal, colorful, repetitive, and even created mechanically.

Here, we're going to look at a pop-art portrait, creating it using Photoshop's layers as well as its clever Smart Objects and Smart Filters, which retain the information you used to create them, and allow you to go back and tweak them after you've committed to the effect. If you don't like what you see, you can erase an entire section of your work and start again—it's a very pop-art method of creating a portrait, so it seems appropriate to build something hard-edged and influenced by comic books. **–IAN EVENDEN**

1 SELECT AND MASK

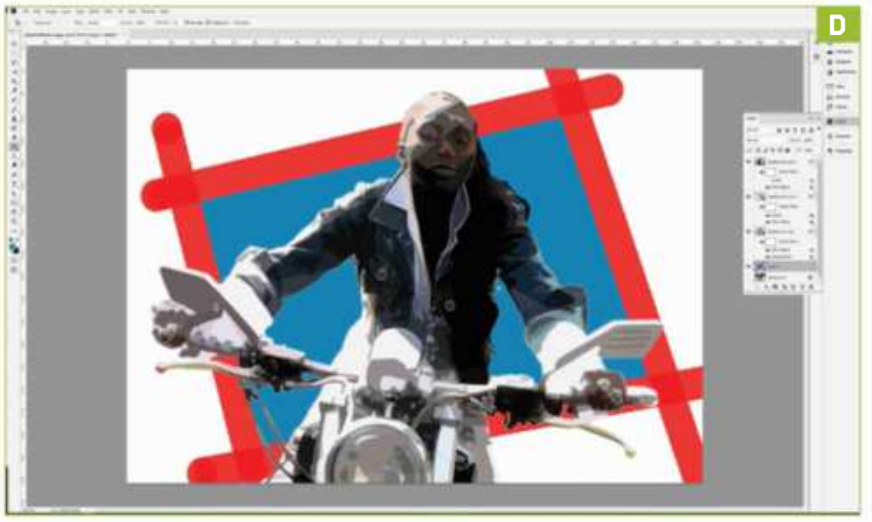
The first thing to do is separate your portrait sitter from the background. Choosing an image with a clean backdrop inevitably makes this easier, but if you've got a busy background, Photoshop can help you out. We used the Quick Selection tool's "Select Subject" option, found on the toolbar at the top of the interface, to make a rough automatic selection, before refining it with the "+" and "-" options, to make sure the young lady and her motorbike were selected, even though the colors were very similar in places to what's behind her. Then, for further refinement, we chose "Select and Mask" from the "Select" menu, and used "Smooth" to remove any rough corners, and "Smart Edge Detection" to lock the selection outline to the edges of our subject [**Image A**]. When you're done, set "Output" to be a new layer with a layer mask, and hit "OK."

2 LAYERS

In the Layers palette, your original Background layer should now be hidden, and a new backgroundless layer has appeared on top, called Background Copy. Create a new layer using the square-with-an-upturned-corner button at the bottom of the palette, and drag it below the Background Copy layer. Fill the new layer with white—if it's your background color (press D to change to the default black foreground and white background), you can press Ctrl-Backspace to do this. Just make sure you've got the right layer selected. Alternatively, you could set white as your foreground color (D followed by X), and use the Bucket tool. Next, right-click the top layer, and choose "Convert to Smart Object." This has the effect of changing all the filters we apply to it into smart filters, which can be altered after they've been applied. Now, using the same right-click menu, duplicate the layer twice. We need a couple of copies to perform different edits on, before blending them back together for the final look. By default, the new layers are called "Background Copy 2" and "Background Copy 3."

3 BLURRING

Hide the top two layers using the eye icon and work on the original Background Copy. Open the "Gaussian Blur" filter from the "Filter" menu, and apply it to the layer with a "Radius" of around four pixels. We want an unfocused look, rather than a complete destruction. When done, head back to the "Filter" menu and choose "Filter Gallery"—we want "Cutout," from the "Artistic" folder. There are some options on the right of the new window—we want the image to be simplified but recognizable, so use the "Number of Levels" slider to achieve this. Somewhere in the four to six range should work. It's a complex filter that can take a while to reprocess its preview when you change something, so



don't be surprised if you move a slider and nothing happens for a moment. We found keeping "Levels" low but turning the "Edge Fidelity" slider all the way up kept our portrait recognizable.

4 A BIT OF BLENDING

Bring back the Background Copy 2 layer using its eye icon, and you'll see the effects of the "Cutout" filter below it disappear. Change the upper layer's blend mode to "Multiply" using the drop-down in the "Layers" palette, and you should see the two blend together, but become darker. This is what "Multiply" does—multiplies the numeric values of the colors being blended together, then divides the result by 255. It always ends up darker. Make sure Background Copy 2 is selected, and open "Filter Gallery → Cutout" again, but this time go for a higher number of "Levels," say eight, with high "Edge Simplicity" and low "Fidelity" [**Image B**]. The preview doesn't show the blended result; you won't see that until you hit "OK."

5 LEVELS

With Background Copy 2 still selected, open "Image → Adjustments → Levels," and drag the white triangle at the right of the histogram to the left. This redefines the brightness of colors in the image that are rendered as pure white, and brightens all colors as it does. Drag it left until you're happy with the result—we're looking for good definition in the face, which had been darkened by our use of "Multiply."

6 MORE FILTERING

Make the top layer, Background Copy 3, visible using its eye icon, and click it so it's active. Head back to the "Filter Gallery," but this time choose "Glowing Edges," which is the only filter in the "Stylize" folder. You'll see an immediate effect, but can alter it using the sliders to the right. You want "Brightness" and "Smoothness" to be quite high, but "Width" to be low [**Image C**]. Blend this layer with those below by changing its "Blend Mode" to "Subtract" using the drop-down (experiment here—we found "Lighter Color" also worked well). Use "Levels" on the layer if it needs brightening up.

7 FINAL TWEAKS

Because we applied the filters as smart filters, we can go back and tweak them by clicking their entries in the "Layers" palette. You can also use the plain white Layer 1 we created in step two to create a background for your image [**Image D**]. Save your work as a PSD to preserve the layers, and use "File → Export" to create a JPG or PNG version for posting online.

FURTHER ADVENTURES IN SMART FILTERS

Every filter except Liquify and Vanishing Point can be applied as a Smart Filter. To edit their settings, double-click their entry in the Layers palette, and the original filter window appears. Once you've finished the composition, editing the Gaussian Blur effect we added in step three can have an interesting result—increasing the Radius to 9 brings in what's almost a depth of field effect, adding a slight 3D feel to the portrait that wasn't there before. Increasing it further destroys the solid figure that was the basis of the composition, and lighter areas begin to dissolve away.

Smart Filters can also be blended, just like a layer. Double click the parallel-lines-with-two-triangles icon to the right of the Filter Gallery entries in the Layers palette, and you'll get a Blending Options window that enables you to control how the filter effect interacts with the pixels below it in the Layers stack. Doing this can radically change the brightness of the Cutout layers in your composition.

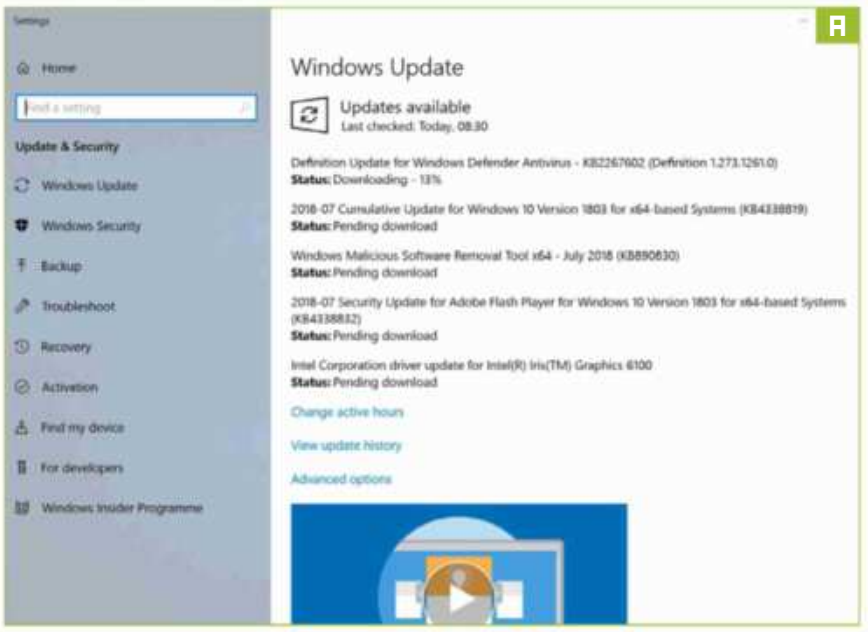
Tighten Up Your PC's Security

YOU'LL NEED THIS

WINDOWS 10
If you have an older version of Windows, you should also use a third-party antivirus app.

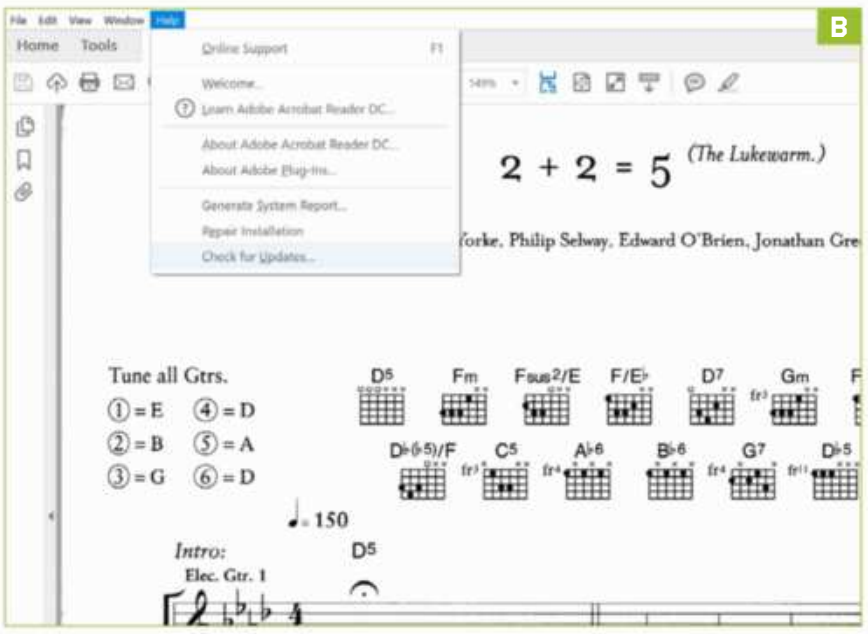
IT'S A JUNGLE OUT THERE. When we go online, we have to battle the various villains that roam the Internet: malicious software, people trying to access our online accounts, fake "phishing" links, and other unpleasantness. The good news is that Windows comes with a great range of tools to help keep you safe, and they're not difficult to use or complicated to set up. In this tutorial, you'll discover the key Windows features that help keep your PC protected, and how you can make sure they're working properly.

Our screenshots are of Windows 10, the safest version of Windows yet, but the tools and features we talk about work just fine in older versions, too. For those Windows versions, we recommend using a third-party antivirus program, but other than that, the security features work much the same way in every version of Windows since Vista. –CARRIE MARSHALL



1 UPDATE WINDOWS

Many security problems have already been solved, and Microsoft regularly updates Windows to fix bugs and potential issues. However, those updates only work if you have them installed on your PC, and the best way to do that is to have automatic updates enabled in "Settings → Windows Update" [**Image A**]. If you don't want automatic updates, make sure you regularly check for them yourself.



2 HAVE EFFECTIVE ANTIVIRUS

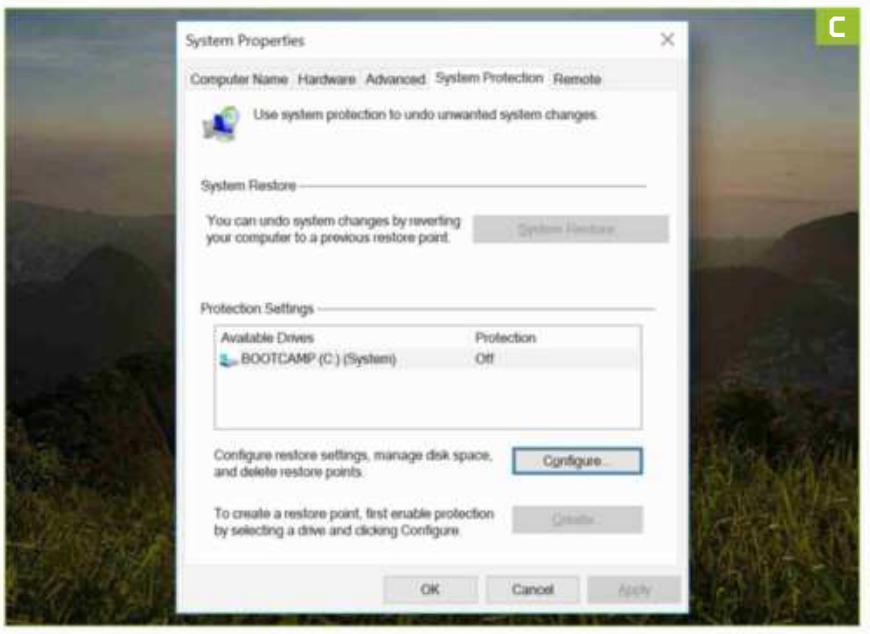
Windows 10 comes with its own built-in security software, Windows Defender Security Center. If you're running an earlier version of Windows, however, we recommend installing a third-party program, such as AVG Free (www.avg.com) or Avast (www.avast.com). Whatever antivirus software you have, though, it's crucial that you keep it up to date by downloading the newest database—new viruses and other kinds of malicious software are discovered daily.

3 UPDATE YOUR APPS

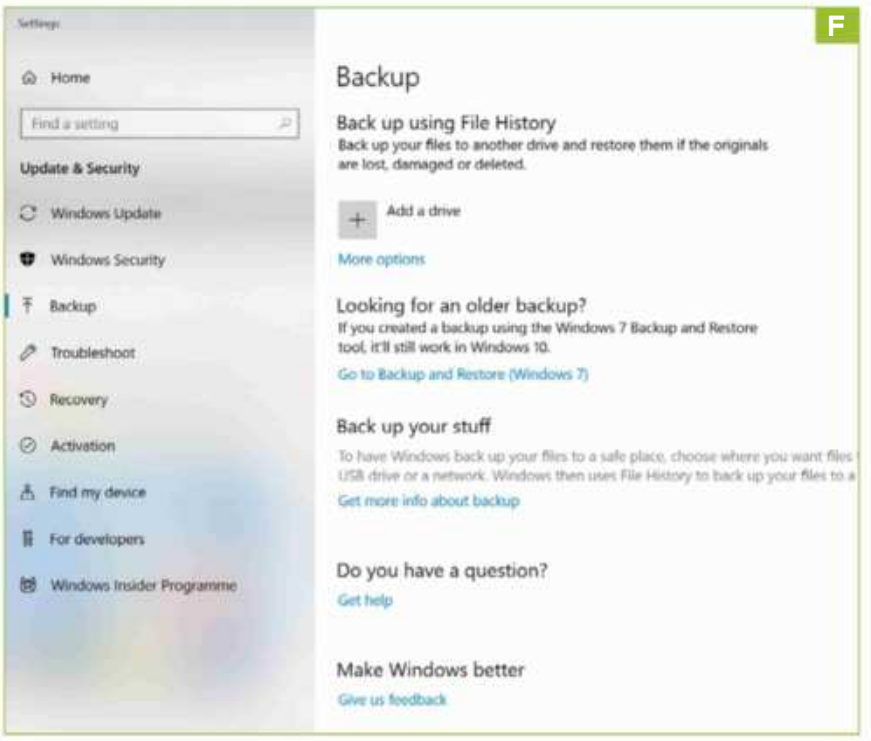
You've updated Windows and your antivirus—what about Adobe Reader [**Image B**] or Flash Player? Those apps, and many like them, are often targeted by the people who make malicious software, because they know that lots of PC users don't update them. Some apps nag you every time an update is available—Adobe Reader, for example—but others require you to do so manually.

4 CREATE A RESTORE POINT

When you know you have a trouble-free PC, make a system Restore Point. This means that if you get infected or suffer from malicious software, you can turn back time on your PC, and restore it to



D
Microsoft
Store
Products
Support
Account
Your info
Privacy
Security
Rewards
Set up two-step verification
Two-step verification adds an extra layer of protection to your account. After you've turn
provide this security code to you only.
In the following steps, we'll help you:
1. Make sure you have up-to-date security info where you can receive security codes.
2. Set up an authenticator app if you have a smartphone. (With an authenticator app,
3. Print or write down your recovery code.
4. Create app passwords for apps and devices (such as Xbox 360, Windows Phone 8 (
codes.
Next
Cancel



pristine condition. To create one, search for "Restore Point," then click "Create A Restore Point → System Properties." On Windows 10, you need to enable "System Restore" in the "Configure" section [**Image C**].

5 USE STRONG PASSWORDS

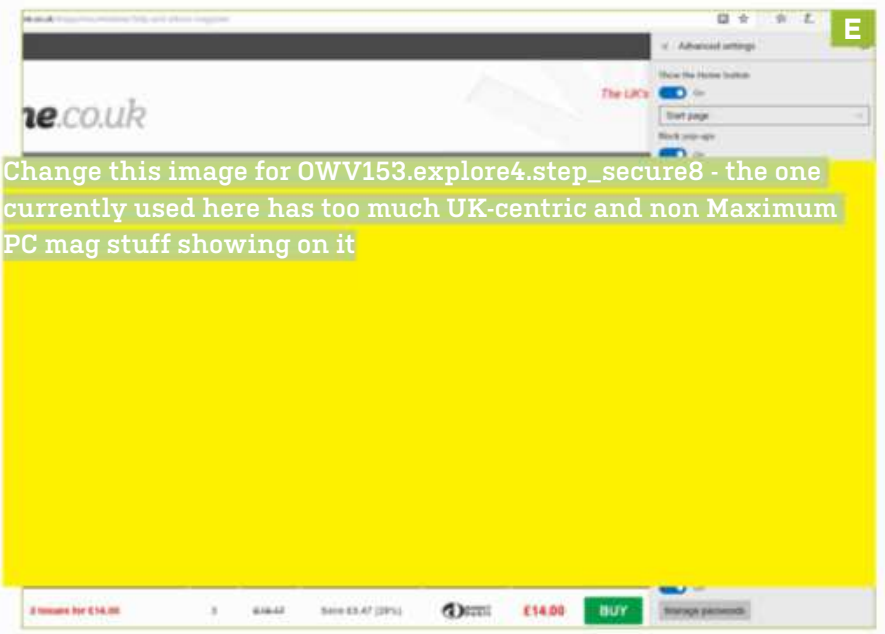
The most commonly used passwords include "123456," "qwerty," and "password." Using them is a terrible idea. Baddies' software can guess simple passwords in a fraction of a second, and if you use the same password on multiple sites and services, they can access everything you do. If you're rubbish at remembering passwords, get an app such as LastPass (www.lastpass.com) to suggest and store them for you.

6 USE TWO-STEP VERIFICATION

Wherever possible, use two-step verification—also known as two-factor authentication—to protect you when online. This adds an extra layer of security whenever you log in to a site on a computer or device it doesn't recognize; this typically sends a code to your cell phone, and without the code, you can't get in. You can enable it on your Microsoft account in the Security Basics page [**Image D**].

7 SET APP PASSWORDS

For even stronger security, you can create app passwords, which are unique passwords for specific apps and devices


E
Change this image for OWV153.explore4.step_secure8 - the one currently used here has too much UK-centric and non Maximum PC mag stuff showing on it
BUY

—so, you would have one password for your Outlook mail on your home PC, for instance, and a different password for the same account on your tablet or phone. You need two-step verification enabled to use this; do that via your Microsoft Account Security Basics.

8 SET THE FIREWALL

Every PC has open ports, the tech equivalent of doors. They allow data to pass back and forth, but they can be used by malicious software, too. A firewall is a piece of software that blocks any doors that aren't being used by approved apps, and Windows has a firewall built in [**Image E**]. You'll find it in the "System and Security" section of Control Panel, so make sure it's switched on, unless you have a separate firewall app installed.

9 BLOCK POP-UPS

Pop-up windows are often used to display convincing but fake error messages, or to load malicious content. The Edge web browser in Windows 10 blocks pop-ups by default, but if you use a different browser, you may need to enable the feature in the software's "Options" menu. If you want to block almost all ads, you might want to install an ad-blocking browser extension.

10 BACK UP EVERYTHING

No matter how secure you make your PC and the services you use, things can still go wrong. We've seen big-name firms hacked and their customers compromised, and laptops can be stolen. It's important to prepare for disaster, and have a backup of anything important [**Image F**]—not on your PC, but on a separate device, such as an external drive or a cloud service, such as OneDrive.

KEEP KIDS SAFE

Don't forget about your children. Take some time to set up parental controls, to limit what they can access on the family PC.

BUILD IT

ALAN DEXTER, EXECUTIVE EDITOR

Tracing the Rays of the Future

Nvidia's RTX graphics cards may be ahead of their time, but what sort of rig can you build with one now?

LENGTH OF TIME: **2-3 HOURS**

LEVEL OF DIFFICULTY: **MEDIUM**

THE CONCEPT

ON THE SURFACE, this should be a fairly straightforward "Build It." The remit is simple enough: Piece together a reasonable home for Nvidia's latest and greatest graphics card, the GeForce RTX 2080 Ti. Having said that, the word "reasonable" takes on a slightly different angle when said graphics card is going to set you back $1,400. Plus, there's the added fun that we don't know for sure which processor is going to give this new silicon the necessary room to strut its stuff, because we're in unknown territory when it comes to ray tracing. Do we want more cores, faster single-core performance, or some hitherto unknown combination of the two?

We briefly toyed with the idea of pairing this new graphics card with Intel's even newer Core i9-9900K, which you'll find reviewed on page 78. We backed out of that idea, though, as we felt that we'd be treading on the toes of the forthcoming Dream Machine (while we haven't made the final decision on the CPU for that build yet, the Core i9-9900K is in the running). The other reason we didn't want to build with the new Intel CPU is that building with two completely new pieces of gear is just asking for trouble—much better to go with something that you know for certain just works.

So, the star of the show here is the graphics card, pure and simple. And while we don't entirely know how everything is going to shape up for the future of hybrid rendering, we do need to give that card room to breathe. That means plenty of RAM and storage, and all ensconced in the kind of case that shows off your new super-expensive polygon-pushing pride and joy.

FUTURE-PROOFING

WE CAN'T ESCAPE THE FACT that the GeForce RTX 2080 Ti is really expensive. We've opted for a third-party offering, with the overclocked, triple-cooler card from Asus providing the reason for this machine's existence. To make sure it's kept fed with data, the rest of the build is pricey as well. To be fair, though, you wouldn't want to slide a $1,400 graphics card into a bargain-basement budget rig.

For the heavy lifting, we've turned to Intel's current top-end CPU, the Core i7-8086K. At least, it was top-end until Intel released its new processors as we were writing this, but as the 9000-series family hasn't been fully unleashed yet, we'll stick with what we know is a strong gaming processor. Capable of turboing up to 5GHz on more thread-shy titles, and offering six physical cores (that's 12 threads, thanks to Hyper-Threading) to more modern titles, this processor can handle the most cutting-edge of games with ease.

Processor and graphics card sorted, the next big decision is what motherboard to use, and here we've elected to use the Asus ROG Maximus X Formula to provide the backbone for the machine. This is a top-end board, with plenty of quality features, including decent audio, integrated Wi-Fi, and RGB Armor to keep the build looking sleek, as well as colorful. The solid steel backplate means there's no flexing when you're building, either.

32GB of RAM and a 1TB M.2 SSD mean that we're not hanging around waiting for our next game to load, and also ensure that we have a speedy experience in Windows and more serious titles as well. Finishing off the specification, we have a Raijintek Orcus 240 AIO cooler that we've been keen to try for a while, a quality Be Quiet! 850W PSU, and for the case we've turned to the Corsair Obsidian 500D, which is a striking-looking chassis for any high-end build. Oh, and don't forget a copy of Windows 10 while you're at it.

INGREDIENTS

PART		STREET PRICE
Case	Corsair Obsidian Series 500D	**$120**
Motherboard	Asus ROG Maximus X Formula	**$280**
CPU	Intel Core i7-8086K	**$440**
CPU Cooler	Raijintek Orcus 240	**$140**
GPU	Asus Strix GeForce RTX 2080 Ti OC	**$1,400**
Memory	32GB (4x 8GB) HyperX Predator DDR4 @ 2,400MT/s	**$316**
PSU	Be Quiet! Straight Power 11 850W	**$170**
Storage	Samsung 970 Evo 1TB M.2 SSD	**$278**
OS	Windows 10 64-bit OEM	**$95**
Total		**$3,239**

1 STRIPPED DOWN

WE LOVE STARTING a build by stripping the case down to the absolute minimum, and that's exactly how we got the ball rolling here, although in this instance, there isn't a lot to remove. The Corsair Obsidian Series 500D is an open design, and easy to work in from the get-go. Popping off the doors is simple, and doesn't require any tools, because they're held in place with a magnetic strip. Simply swing them open and lift them off the hinges, and you've got easy access to everything. Spinning the machine around, the only obvious thing to temporarily remove is the cable cover, which again is simple to do. The drive cages on the rear can be popped out too (thumbscrews abound), and you can ease out the dust filters as well (which are held in place magnetically), although you don't need to do so to start building.

2 STANDING OFF

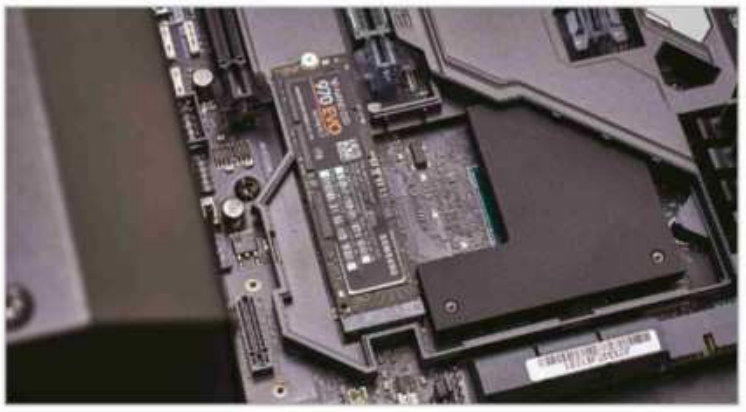
TIME TO BUILD. The Asus ROG Maximus X Formula is a solid, heavy motherboard, but easing it into the awaiting space instantly threw up an issue—it wouldn't lay flat, due to a location peg in the center of the motherboard. We sometimes see these used to help out during installation, but here we found it slightly misaligned, forcing us to remove it. Once done, it was still a tight squeeze getting the motherboard into place, in part because it boasts an integrated I/O plate. That and the fact that there isn't much clearance at the bottom of the case, due to the PSU cover. There is a trend for I/O plates to be used on high-end motherboards, but it's worth knowing that they can be tricky to install, even in more open cases, like this one.

3 CORE COMPONENTS

WITH THE MOTHERBOARD in place, we can now start installing components. Normally, we would install the CPU outside of the case, just because it can be a little tight, but there really is so much space inside the Obsidian 500D, that this wasn't an issue. In fact, we had more trouble with the motherboard's Armor than we did the case, although this was more of a problem when it came to installing the cooler, but we'll come back to that later. The RAM was the next thing to install, and sliding all four sticks into place is as pleasing as it is capacious. Again, there's plenty of room to do so—the fact that there's no front drive cage helps here.

4 COOL DRIVING

M.2 SSDs CAN GET HOT under load, so it's a good idea to have a decent heat spreader present. The one you'll find on the Maximus X Formula is particularly huge, and you'll find it as part of the large ROG eye logo, toward the bottom-right of the motherboard. Releasing the three screws on this plate enables you to remove it and reveal the M.2 connector. We were momentarily thrown by the fact that the retention screw for the drive wasn't preinstalled, but actually in the motherboard box—it took longer than it should have for us realize this. Once found, though, securing the 1TB Samsung 970 Evo SSD was easy, and that huge cooler means that it shouldn't be throttling anytime soon. It's worth noting that it isn't easy to access this drive once your graphics card is installed, but this is often the case with the location of M.2 connectors.



5 THERMAL CONSIDERATIONS

IT'S AT THIS POINT in the build where things can get tricky, and sure enough, installing the cooler had us wishing that we had a spare hand. It's actually a great system once everything is set up, because the cooler is held in place by just two screws, but getting to that stage isn't easy. You have to hold the backplate in place on the rear of the motherboard while screwing another plate into place on the processor side—long arms are essential; a spare hand or two useful. We elected to place the radiator in the front of the case, to keep things clear at the top, but an argument could be made for roof-mounting instead. It's worth noting that the pump isn't integrated into the CPU block, so ensure you plug this and the various fan cables into your motherboard.

6 TRACING RAYS

IT'S TIME FOR THE STAR of the show, the Asus Strix GeForce RTX 2080 Ti OC, to get eased into position. After removing the two blanking plates, this is straightforward, although care is needed because this is a heavy card, and you don't want to drop it on to your motherboard. If you get a PCIe extension cable, this case does support vertical mounting of your graphics card, which would look great against the side panel's smoked glass, but these things aren't cheap, and we've already dropped a big chunk of cash on this machine. Still, it's an option. At this point, we installed the power supply, and discreetly threaded the various cables through to where they were needed. The top eight-pin EPS connector can often be tricky, but we had cable to spare here.

1 **The Raijintek Orcus 240 is an impressive cooler, with a healthy array of lighting options, and it even comes with a remote control.**

2 **The star of the show is the RTX 2080 Ti, which is a beast of a card, taking up plenty of room, even in this large case.**

3 **The power supply shroud does a good job of keeping the build clean, with all the major cabling hidden in the rear.**

GAMER'S DELIGHT

THERE WERE NO NASTY surprises putting this machine together, other than the final price—although we feared this was always going to be the case with Nvidia's latest and greatest GPU. You could easily spend a whole lot more, and the core performance wouldn't change too much, while spending less could well throw a monkey wrench in the works. This isn't a budget build by any stretch, but it is probably the most affordable way of building an RTX 2080 Ti machine that isn't held back by the processor or storage.

The trickiest part of the build involved the cooler, and we could have mitigated this by installing the bracket outside of the case, simply because holding the backplate in place would have been easier (and wouldn't have required quite so many hands). We could have gone for a 360mm radiator in the front as well, which would have improved airflow further, although we didn't have a problem with heat in this machine anyway. The fact that you can control the lighting of the cooler using the tiny remote was a bit of a bonus, though, and it can look pretty if you care about such things.

The goal of this build was to piece together a cutting-edge gaming machine that will survive the ravages of time, and give the RTX 2080 Ti the best possible future. We feel we hit this brief pretty convincingly, and the benchmarks would seem to back that up, with some impressive results when compared to our zero-point machine. The *Total War: Warhammer II* result, which rolled in 120 percent better than our zero-point, shows the kind of improvement that is possible with this new graphics card, although this is over the older GTX 1080.

At this point, we're still not sure how the RTX 2080 Ti performs in real-time ray-tracing titles or DLSS, but we'll revisit the performance at these tasks in a future issue, possibly with this build (if we haven't stripped it down by then). For now, this certainly makes for a smooth gaming experience, and returning to a normal gaming machine after using this on a 4K screen makes for an uncomfortable experience.

We like to ask ourselves what we'd change at the end of every build. Here, we're not sure that anything stands out. The case is a delight to work in, and looks great when all the cabling is tucked out of sight. We are tempted to try mounting the graphics card vertically, and this could be the chassis that pushes us over the edge to try it, especially if we use a graphics card that lights up as much as the rest of this system.

BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi (Index)	959	1,399 (46%)
CrystalDisk QD32 Sequential Read (MB/s)	3,422	3,512 (3%)
CrystalDisk QD32 Sequential Write (MB/s)	1,706	2,510 (47%)
Rise of the Tomb Raider (fps)	93	154 (66%)
Total War: Warhammer II (fps)	55	121 (120%)
Tom Clancy's Ghost Recon Wildlands (Avg fps)	48	83 (73%)
3DMark: Fire Strike Extreme (Index)	9,128	15,611 (71%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our zero-point consists of an Intel Core i5-8400, 16GB of Corsair Vengeance LPX @ 2666, an MSI GeForce GTX 1080 Armor, and a 500GB 960 Evo M.2 PCIe SSD. All tests were performed at 1440p at the highest graphical profile.

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REVIEWS

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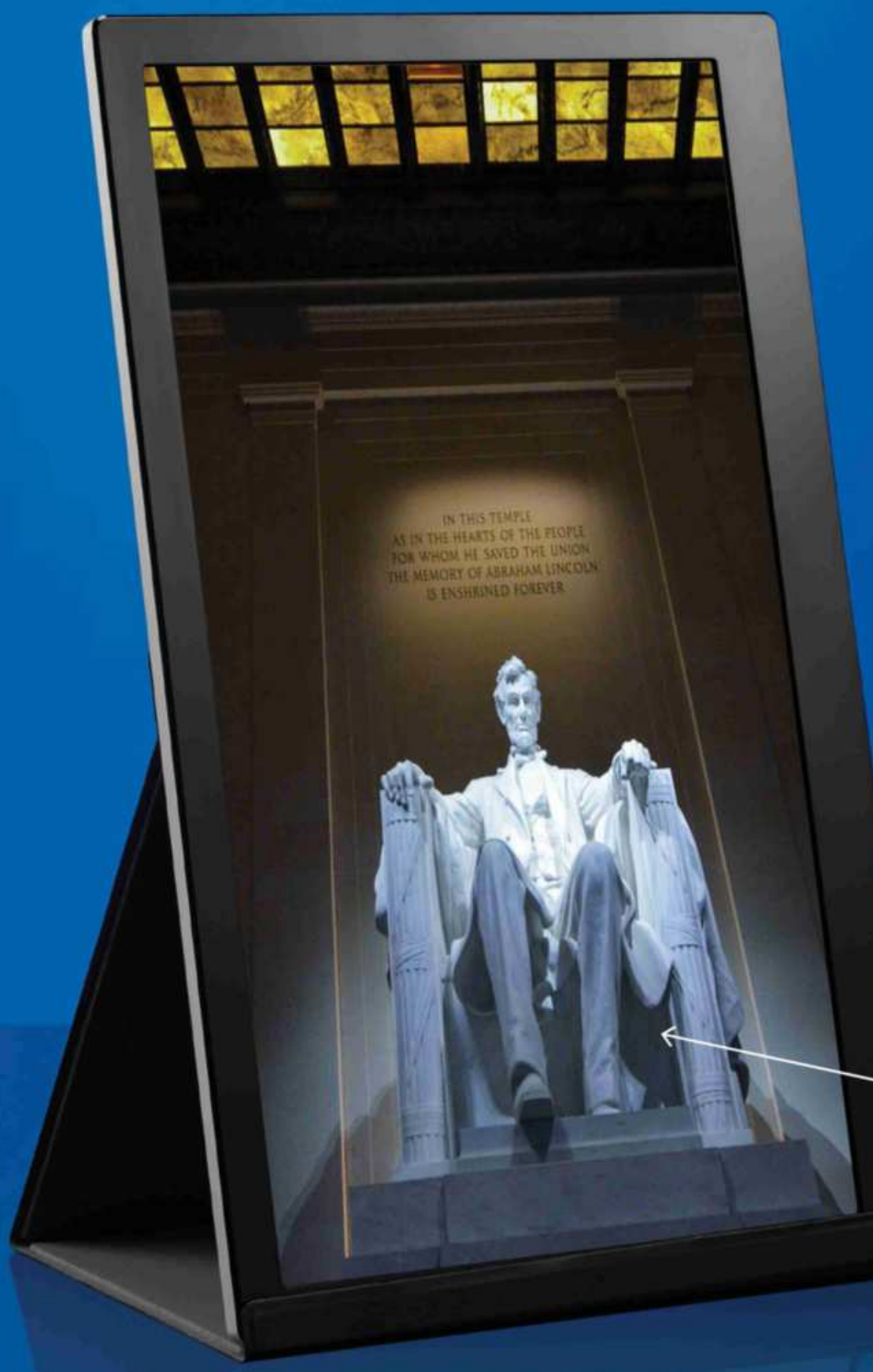
IN THIS TEMPLE
AS IN THE HEARTS OF THE PEOPLE
FOR WHOM HE SAVED THE UNION
THE MEMORY OF ABRAHAM LINCOLN
IS ENSHRINED FOREVER
AOC

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Nvidia GeForce RTX 2080 Ti FE

The new king of the hill, with a princely price

THE MARCH OF PROGRESS usually has a stately pace, but sometimes you need to throw caution to the wind, stomp on the accelerator, and see just how fast you can go. That seems to be what Nvidia is doing with its Turing architecture, and it's what it hopes gamers will do with their wallets.

The RTX 2080 Ti gets you the full kitchen-sink experience. It boasts 21 percent more CUDA cores than the 1080 Ti, and with RT cores and Tensor cores to help accelerate ray tracing and deep-learning calculations, Turing is built for the future. Nvidia is hyping up the ray-tracing angle, but the deep-learning elements may prove more useful in the long run. The great thing is that you get both. Unlike the RTX 2080, the 2080 Ti doesn't trade blows with the 1080 Ti. It wins every comparison, and makes 4K gaming at maximum quality viable. It even beats the Titan V in gaming performance.

But there's a price to pay, literally. The RTX 2080 Ti Founders Edition costs as much as the Titan Xp, a card that was never about value. For a non-Titan graphics card that's ostensibly for the consumer market, and not counting dual-GPU solutions, RTX 2080 Ti is Nvidia's most expensive GPU by a long shot. Even the base price of $999 for reference model cards is hard to justify. If you're an enthusiast, though, you'll still want one.

At 1440p, the 2080 Ti is over 25 percent faster than the 1080 Ti on average, and nearly 35 percent faster at 4K. That's with existing games that don't even use the RT cores or DLSS. There are other features in the Turing architecture, such as mesh shaders, variable rate shaders, multi-view rendering, and texture space shading. As games begin leveraging the new hardware and its features, don't be surprised if the 2080 Ti extends its lead.

And there's the rub. We've seen plenty of great graphics ideas and demos in the past that never got much traction. There are 11 announced games that plan to support ray tracing, and 25 that will use DLSS, but none is available yet—at least, the DLSS and ray-tracing patches aren't available. Buying the 2080 Ti for potential future gains involves risk. And with TSMC already doing volume shipments of its new 7nm process (used in the Apple A12 SoC in the iPhone XS), we might see a die shrink of Turing next year that will make the current version look tame.

A big part of why Nvidia can take such a risk with Turing, delivering only modest

increases in graphics performance, but adding lots of costly new features, is because AMD's GPU division hasn't provided any serious competition in the past few years. AMD has nothing that can compete with the 1080 Ti in performance, never mind the 2080 Ti. A third refresh of the Polaris architecture is incoming, aiming at the larger $200 graphics card market, but where's the glory in building a competitive and value-focused sedan?

Nvidia remains the only game in town if you're after a hot-rod graphics card, with the RTX 2080 Ti as the standard bearer. A future RTX Titan may be waiting in the wings—because even the 2080 Ti doesn't enable the full TU102 chip—but we don't even want to think about what it will cost. The RTX 2080 Ti is here right now, delivering uncompromising performance. If you're thinking about investing in a 4K 144Hz HDR G-Sync monitor, this is the card for you. People may complain about the price, but secretly they wish they could justify the purchase. **–JARRED WALTON**

BENCHMARKS

	Nvidia GeForce RTX 2080 Ti FE	Nvidia GeForce GTX 1080 Ti
Assassin's Creed Origins (Avg fps)	**95/64**	78/50
Deus Ex: Mankind Divided (Avg fps)	**93/53**	70/38
Far Cry 5 (Avg fps)	**130/74**	105/56
Grand Theft Auto 5 (Avg fps)	**101/56**	85/45
Middle Earth: Shadow of War (Avg fps)	**111/67**	83/48
Rise of the Tomb Raider (Avg fps)	**114/64**	89/49
Total War: Warhammer II (Avg fps)	**107/73**	95/56

Best scores are in bold. Our test bed consists of an Intel Core i7-8700K, 16GB of G.Skill DDR4-3200, an MSI Z370 Gaming Pro Carbon, and a 500GB Samsung 960 Evo M.2. All games are tested at their highest graphical profile with AA turned up, at 1440p and 4K.

VERDICT **8**

Nvidia GeForce RTX 2080 Ti FE

EXOTIC Fastest GPU; packed with features; built for 4K.

EXCESSIVE Titan pricing; no ray-tracing games yet; diminishing gains.

$1,200, www.nvidia.com

SPECIFICATIONS

GPU	TU102
Lithography	TSMC 12nm FinFET
Transistor Count	18.6 billion
CUDA Cores	4,352
Texture Units	272
ROPs	88
Core/Boost Clock	1,350/1,545MHz
Memory Capacity & Type	11GB GDDR6
Memory Speed	14GT/s
Memory Bus	352-bit
TDP	265W
Display Connectors	2x DisplayPort, 1x HDMI, 1x USB Type C

One ray per second had better be worth that price tag.

Intel Core i9-9900K

Even more mainstream cores from Intel

CAST YOUR MIND back to late 2006. That's when Intel introduced its first desktop quad-core CPU. Fast-forward nearly 11 years later to summer 2017, and what had changed? In terms of core counts, not much. Intel's mainstream desktop socket was still limited to just four cores.

OK, you could buy so-called desktop chips with more than four cores, but they were part of what was and remains today a series of rebadged server platforms, complete with costly multi-channel memory controllers, and other features that up the price but do little to enhance the desktop computing experience. Yet here we are in late 2018, reviewing a mainstream eight-core CPU from Intel, just a year after it unveiled its first six-core mainstream chips. What, exactly, is going on?

The answer is Ryzen. Whatever Intel or anyone else says, there is no way the new Core i9-9900K would exist without the arrival of AMD's fantastic new Ryzen CPU last year. Ryzen isn't perfect, but it has been good enough to wake Intel from its slumber. The result is a rapid acceleration of Intel's road map, and a doubling of its mainstream desktop core count in little more than a year.

The new 9900K fits into a larger refresh of CPUs for the mainstream LGA1151 socket. This is Intel, of course, so the precise makeup of the new 9th Gen family isn't just difficult to get your head around; it's actually frustrating. That's chiefly because with this new 9000 series of CPUs, Intel has once again rejigged its HyperThreading implementation. Put simply, HyperThreading is gone, save for the top-end eight-core 9900K processor with 16 threads. That's frustrating, because the feature remains present in all the chips—Intel has simply disabled it in order to create an artificial product hierarchy.

All that absorbed, how does this range-topping member of the new 9th Gen series perform? Intel rates it at 3.6GHz base clock, and has set the maximum Turbo frequency at 5GHz—just remember, the latter is not an all-cores frequency. Nevertheless, it does ensure the new 9900K delivers epic single-threaded performance. It's on a par with the existing single-thread king, the Core i7-8086K, in that regard.

Predictably, the 9900K sets a new standard for mainstream chips when it comes to multithreaded performance, too. Yes, it duly tears AMD's top Ryzen chip, the 2700X, a new one across the board. In fact, in a desktop context, it's quick enough to make the likes of Intel's 10-core 7900X, a server-derived CPU for the LGA2011 socket, look redundant.

Inevitably, the 9900K's one arguable weakness involves overclocking. At stock settings, it typically runs at 4.7GHz across all eight cores when under heavy load. We managed to crank that up to 5GHz on all cores. That's a six-and-a-bit percent overclock, and not enough to really impact your subjective computing experience in the real world. Given the number of cores and the already high clock speeds Intel has enabled as standard for the 9900K, the limited scope for overclocking is not a surprise.

The final piece of the puzzle is motherboard compatibility, and the news is about as good as we could hope for. The 9900K and the rest of the new 9th Gen gang are compatible with existing 300 Series motherboard chipsets, although actual mileage will vary from board to board. As ever, check with the manufacturer for details regarding required BIOS updates.

In isolation, then, the new 9900K is a fantastic chip. It's the quickest true desktop CPU yet. Priced at $530, it's even reasonable value by Intel's standards. Instead, it's with the other members of the new 9th Gen range that our doubt resides. How will an eight-core, eight-thread chip like the new Core i7-9700K compare with the six-core, 12-thread Core i7-8700K? Now, that's an interesting question. **–JEREMY LAIRD**

PROCESSOR BENCHMARKS

	Intel Core i9-9900K	Intel Core i7-8086K	AMD Ryzen 7 2700X
Cinebench R15 Single (Index)	**214**	212	180
Cinebench R15 Multi (Index)	**1,994**	1,630	1,814
Tech ARP's X264 (Avg fps)	**42.69**	35.98	31.71
Fry Render (m:s)	**01:49**	02:08	02:14
AIDA64 Memory Latency (ns)	**47.7**	49.1	68.4
AIDA64 Memory Bandwidth (MB/s)	46,144	46,451	**46,506**
Power Draw Idle/Load (Watts)	**65/185**	69/200	91/221
Total War: Warhammer II (fps)	**84**	**84**	76
Ghost Recon Wildlands (fps)	**62**	61	55
Middle Earth: Shadow of War (fps)	**95**	**95**	86
3DMark Fire Strike (Index)	19,428	**19,563**	17,855
Maximum Overclock @ Voltage (GHz @ V)	5.0 @ Auto	**5.2 @ 1.36V**	4.2 @ 1.45V
Price to Performance (Index)	3.76	3.70	**5.50**

Best scores are in bold. Our test bed consists of an Asus Maximus X Formula, an Asus Crosshair VI Hero, 16GB (2x 8GB) of Corsair Dominator Platinum, and an Nvidia GeForce GTX 1080. All games were tested at 1080p on the highest graphical profile, with average fps noted.

VERDICT **9**

Intel Core i9-9900K

CORE PROPOSITION Huge single-core and multithreaded performance; uses mainstream socket.

CORE OVERLOAD Not much overclocking headroom; not exactly affordable.

$530, www.intel.com

SPECIFICATIONS

Base Clock	3.6GHz
Turbo Clock	5GHz
Cores/Threads	8/16
Lithography	14nm
Cache	16MB L3
Memory Support	DDR4-2666
Memory Channels	Dual
Max PCIe Lanes	20
Socket	LGA1151
TDP	95W

The Core i9-9900K is Intel's first mainstream eight-core CPU.

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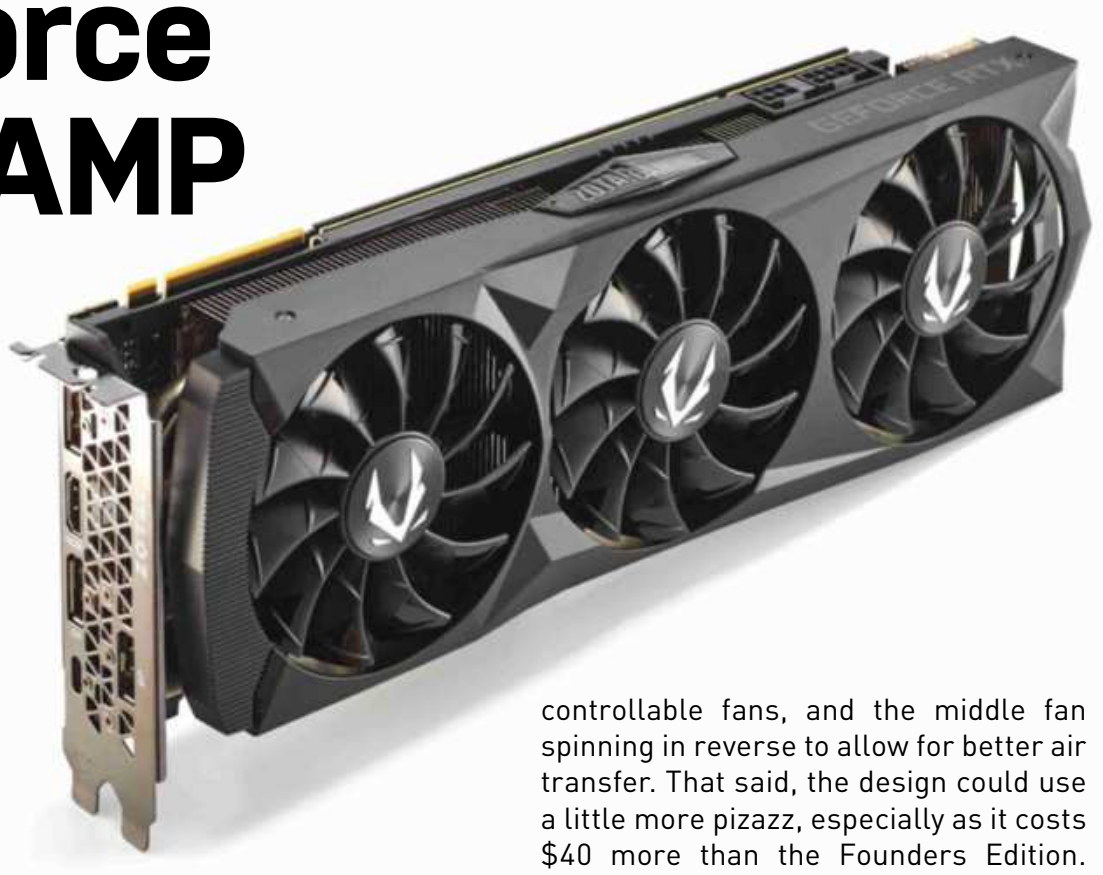
Zotac GeForce RTX 2080 AMP

Aftermarket AIB meets RTX 2080



THIS IS GOING to be a tricky review. We looked at the Founders Edition last issue, and found it wanting, so far as generational upgrades are concerned. It's an odd proposition, and not something we can wholeheartedly recommend; its main selling points—ray tracing and DLSS antialiasing—are unknown quantities at the time of writing, and even once the features are supported by Microsoft, we'll probably still be waiting some time for more titles to enable them.

What you're left with is a card that performs the same as a GTX 1080 Ti, but for $140 more. It's a tough one to swallow. That's not to say DLSS and ray tracing aren't interesting concepts, though. Designing dedicated hardware on to which to offload antialiasing is a genius idea, and arguably the future of computing, once we start hitting the true limits of physics. Ray tracing, too, will inevitably be the next step in rendering high-fidelity titles. But, right now, both features require developers to implement them into their games ahead of time.

That's a big problem. Hypothetically, let's say the two cards (2080 and 2080 Ti) account for 2 percent of the dedicated GPU market after six months. A new PC-only AAA title is about to be released. Of that 2 percent, only half likes the look of the game, and is interested in buying it. The developer will be asking, of that 1 percent, how many will buy it regardless of whether it has ray tracing or DLSS? So, is it worth investing time, effort, and money to support those two features, for a tiny percentage of the total sales? The answer: Probably not. And that's a best-case scenario. With most developers working on console titles first—a market dominated by AMD right now, as far as graphics are concerned—those percentages drop even further.

The problem is accessibility—because the cards capable of ray tracing are so expensive, and the uptick in performance so low compared to last gen's leap, the likelihood of either ray tracing or DLSS making it into the mainstream is nothing short of a pipe dream. We need a $220 RTX 2060, capable of driving ray-traced elements at 1080p, to make it a reality.

Enough about that—what about the card? What's the difference between the Founders Edition and the AIBs? Not a lot, outside of the cooler. Zotac's fan solution is exemplary, with individually controllable fans, and the middle fan spinning in reverse to allow for better air transfer. That said, the design could use a little more pizazz, especially as it costs $40 more than the Founders Edition. Performance-wise, it falls exactly where we'd expect, and we struggled to clock it any more than 40MHz higher on the core, even with the voltage unlocked.

Overall, Zotac's RTX 2080 AMP is a bit disappointing. The cooling, although fantastic, isn't enough to alleviate the pain of an additional $40 for something that looks quite basic in contrast to the FE, or even the 1080 Ti AMP. And performance is only what you'd expect. With the RTX series likely to be facing uptake problems, you'd be better off investing in a cheaper 1080 Ti. It performs the same, costs the same, and probably looks a darn sight better, too. **–ZAK STOREY**

BENCHMARKS

	Zotac GeForce RTX 2080 AMP	Asus ROG Strix RTX 2080 OC
Middle Earth: Shadow of War (Avg fps)	**96/58**	**96/58**
Total War: Warhammer II (Avg fps)	**79/44**	**79/44**
Tom Clancy's Ghost Recon: Wildlands (Avg fps)	**63/40**	62/**40**
Rise of the Tomb Raider (Avg fps)	**121/66**	**121/66**
Power Draw Idle/Load (Watts)	76/**390**	**74**/395
3DMark Fire Strike Ultra (Index)	**6,713**	6,701
Price to Performance ($ per fps)	**$9.58**	$9.82

Best scores are in bold. Our test bed consists of an Intel Core i7-8700K, 16GB of G.Skill DDR4-3200, an MSI Z370 Gaming Pro Carbon, and a 500GB Samsung 960 Evo M.2. All games are tested at their highest graphical profile with AA turned up, at 1440p and 4K.

VERDICT 7

Zotac GeForce RTX 2080 AMP

AMP OK performance; strong cooling; subdued style.

SUB Mediocre overclocking; ray tracing and DLSS still not supported; doesn't feel premium; expensive.

$840, www.zotac.com

SPECIFICATIONS

GPU	TU104
Lithography	TSMC 12nm FinFET
CUDA Cores	2,944
ROPs	64
Memory Capacity & Type	8GB GDDR6
TDP	215W
Display Connectors	3x DisplayPort 1.4, 1x HDMI 2.0b, 1x USB-C

BenQ EX3203R

BenQ brings HDR lite to the desktop

STRUGGLING TO KEEP UP with the latest must-have features for gaming monitors, such as 144Hz refresh rates, adaptive sync, curved panels, and low input lag modes? Then prepare to be even more baffled. HDR, or High Dynamic Range, visuals have arrived, and represent perhaps the most complex and confusing technology to yet hit the monitor market.

BenQ's new gaming monitor combines all of the above, and more. In fact, it throws USB-C into the mix, along with a 32-inch diagonal LCD panel, and a gaming-friendly quad-HD 2560x1440 native resolution. On paper, the EX3203R is killer. In practice? It's more complicated.

For starters, not all HDR displays are equal. In fact, good luck finding two that are entirely comparable. Not only are there multiple bodies setting standards, but even within a single standard-setting authority, you'll typically find a tiered hierarchy of HDR certification. The EX3203R is a case in point. It's one of the very first monitors to be awarded VESA's DisplayHDR 400 standard. So, there's no doubt about its HDR credibility. Right?

Not exactly. DisplayHDR 400 is VESA's entry point into HDR. It only requires a peak brightness of 400cd/m^2. Many would argue the full impact of HDR only arrives at 1,000cd/m^2. DisplayHDR 400 also doesn't dictate local dimming capability, and makes less stringent demands for color reproduction; BenQ says the EX3203R is good for 90 percent coverage of the DCI-P3 profile. So, DisplayHDR 400 is probably best viewed as HDR lite.

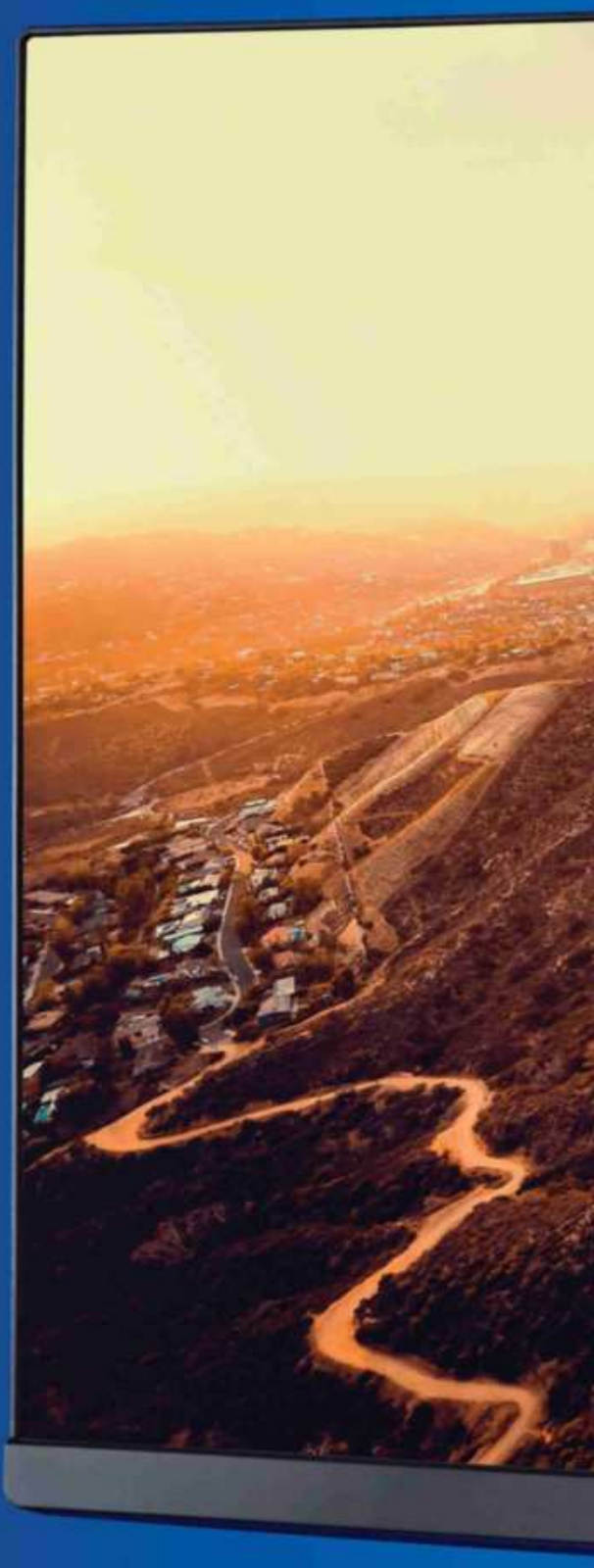
The EX3203R has further on-paper shortcomings. The 32-inch panel uses VA tech. That's great for contrast and eye-popping colors, so makes for a good fit with HDR. But VA is also the slowest of the major LCD panel technologies (the others being TN and IPS) when it comes to pixel response. Not so great for gaming, then.

But if the EX3203R presents a complex theoretical proposition, how does it stack up in practice? Out of the box, it's pretty impressive. The design is restrained for a monitor aimed at least partly at the gaming market, but with slim bezels on three sides and a sleek silver stand, the initial impression is of money well spent.

Odds are, you'll like the look of this from a gaming perspective, too. The colors are seriously punchy, and while 400cd/m^2 may be no great shakes by HDR standards, it's more than bright enough by conventional metrics. Likewise, the EX3203R's panel is rated at 3,000:1 for static contrast capability, and it looks every bit as good as that. The VA panel's relatively subtle gentle curve also makes for a nicely immersive experience, without going to the polarizing extremes of more dramatically curved monitors.

It's worth noting that HDR remains problematical in terms of everything from ensuring it's enabled to the mixed results you get when it is. Enabling HDR globally in Windows, for instance, makes the desktop look very dull. And as a general-purpose monitor, the EX3203R's GPU-friendly 2560x1440 native resolution results in fairly fat and ugly pixels on the desktop. This is no high-DPI display.

The VA panel also prevents the EX3203R from being at the cutting edge in terms of pixel response performance. However, inverse ghosting is not a major issue, and the 144Hz refresh delivers a fantastically smooth experience, provided you have a powerful and probably pricey graphics card. The EX3203R is not entirely free from flaws, and it's not great all around, but it is a pretty compelling gaming companion. **–JEREMY LAIRD**



VERDICT 8

BenQ EX3203R

RANGY Mega feature set; punchy visuals; good gaming fit.

MANGY Arguably not true HDR; not a great multi-purpose panel.

$699, www.benq.com

SPECIFICATIONS

Panel Size	31.5 inches
Native Resolution	2560x1440
Pixel Density	93.24
Panel Type	VA
Maximum Refresh	144Hz
Response	4ms (GtG)
Contrast	3,000:1
Display Inputs	2x HDMI 2.0, DisplayPort 1.2, USB-C
Connectivity	USB
VESA Mount	Requires kit
Warranty	Three years

The EX3203R is one of the first monitors to be awarded VESA's DisplayHDR 400 certification.

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AOC I1601FWUX

IPS screen and USB-C; is this the perfect portable LCD panel?

PORTABILITY AND PLENTY of screen real estate don't normally see eye to eye. However, a recent development is enabling those two ancient foes to become a little more pally. We speak, of course, of USB-C, in all its single-port, multi-function glory.

It's an enabler thanks to three key properties. First is loads of bandwidth, which is essential for driving high-resolution displays. Second is support for DisplayPort alternate mode, and thus the ability to function as a video port without the need for special drivers. Third is the ability to supply much higher power output. USB-C maxes out at 5A and 20V, and thus fully 100 watts. Not every USB-C port will necessarily deliver the full 100 watts, but broadly speaking, if your PC or laptop has a USB-C port, it will be able to supply significant power to any attached peripheral. Put that all together and you have the perfect combination for attaching and driving a compact external display via a single port.

Enter, therefore, the AOC I1601FWUX. It's a 15.6-inch external display, with a FullHD 1080p pixel grid that connects via a single USB-C interface to supply both power and video. It's an appealing idea. The unit itself is compact and light, and broadly comparable to carrying a tablet. It doesn't require charging, although it will, obviously, represent a pretty significant drain on a laptop's battery pack if used away from the grid. All told, it comes in at around two pounds. To put that into context, it's only a little heavier than a 12.9-inch iPad Pro.

As for the primary speeds and feeds, the panel itself is IPS. AOC doesn't get too specific, but it's only claimed to support 262,000 colors, so we're likely talking about a low-end 6-bit-per-channel panel, which is probably fine for this type of application. It's hardly aimed at serious content creation specialists sitting in a studio all day. Elsewhere, AOC claims 5ms response times and maximum 220cd/m^2 brightness; AOC doesn't quote a contrast ratio. Other notable features include a magnetic screen cover that doubles as a stand, plus a single button that provides access to the on-screen menu. The latter makes for a rather laborious configuration process, because it involves pressing the button to cycle through options, and then waiting several seconds for your chosen option to activate. But it's not something you'll be wrestling with regularly, so the quest for simplicity in this regard is understandable.

GREEN SCREEN

The actual performance of the display, however, is a little less so. Given the brightness rating, and the fact that broad compatibility puts a practical limit on how bright this type of display can reasonably be, we weren't expecting fireworks. But the overall impact of AOC's portable panel remains rather underwhelming. Dingy colors with a slightly green-tinged overall balance probably sums it up. When you consider the high quality of LCD panels that are now standard in even the most mundane Android tablets, it's a little difficult to stomach this quality of panel. That said, it's not worse than you typically get in many middle-market laptop PCs.

That's a pity, because the concept and execution is otherwise pretty appealing. 1080p makes for a welcome slice of extra screen real estate, and is plenty for web browsing, running a mail client, viewing documents, and all that stuff. You could also use it with a really small laptop as a screen to watch movies on the move. It's a very handy little gadget to have with you on vacation or work trips.

The I1601FWUX will do all those things and objectively get the job done well enough. But you'd enjoy doing all that a lot more and we'd find it easier to recommend if the LCD panel had a tad more visual pop. Even taking into account the relatively modest $179 entry fee, most users will probably be expecting just a little bit more. –JEREMY LAIRD

VERDICT **7**

AOC I1601FWUX

PORTABLE PERFECTION Compact; single-cable connectivity; decent 1080p resolution.

PORTA-POTTY Disappointing image quality; tedious single-button config.

$179, www.aoc.com

SPECIFICATIONS

Panel Size	15.6 inches
Native Resolution	1920x1080
Pixel Density	141 ppi
Panel Type	IPS
Maximum Refresh	60Hz
Response	5ms
Display Inputs	USB-C
Connectivity	USB-C
VESA Mount	No
Warranty	Three years

Wooting One

It's a keyboard, Jim, but not as we know it

IT'S NOT OFTEN that a keyboard strikes us as special. Many great keyboards cross our desks, many innovative devices, many bells, many whistles. But special keyboards? Not so much. So, does the Wooting One really land in that bucket, or is it merely sloshing around in the pool of very good keyboards that we keep in the corner? We'll tell you: This is special. Very special. It's a combination of supreme style, superior sound, fantastic feel, and tantalizingly innovative technology that sets itself far apart from everything it's even tangentially competing with. We're keeping it. Forget prying it out of our cold, dead hands; we're curling up around it, and developing rigor mortis.

We should probably break down the Wooting One's key gimmick before we go any further. It's an analog keyboard. That sounds weird, and in a way it is. Your keyboard doesn't need to be pressure-sensitive. It's a digital input method, and has been that way forever for good reason. Having your fingers on the keyboard is about speed, accuracy, triggering triggers, and moving on. But even if you never make use of the analog trigger-style functionality, which can track just how far down you've pressed a key and map that to analog control in games, that functionality means you can precisely adjust the actuation point of the keys. Lily-fingered key-skimmer? Keep it high. Hammer-digit bottom-outer? Drop it as low as you can go. Want the same key to do two individual things? You're crazy, but OK, you can do that.

That does lead to a rather unusual feel to the keys, with a consistent level of resistance all the way down—almost, yes, like you're pressing the analog trigger on the back of an Xbox controller, at least if you concentrate on what your fingertips are doing. There's no notch, understandably, so the only truly tactile response you get is at the bottom of the travel. That's going to be a big negative for some people (and we'd usually advocate tactile switches without hesitation), but this isn't the miserable squashiness of a Razer yellow, or the muddy feel of a membrane or membranical board. It's clattery, and it's satisfying. If you're dead set on click, you'll find a bunch of key switches in the box, so you can replace WASD, or any other favorite cluster, with the clicky version of these Flaretech Prism switches—or you could buy the clicky version, which spills them over the whole thing, or a $50 pack of replacement switches for the whole board.

MAGIC MAKERS

Most remarkable? Those cross-topped key switches (which make this an ideal base for customization) aren't plugged in to anything. Pull one of the double-shot caps off, remove the switch, shove your finger in the hole, and you actuate the key—Wooting's infrared optical sensors, beneath each switch, provide the real magic. They mean a super-fast debounce rate, n-key rollover, and room on the top layer of the circuit board for some awesome lighting effects. Great logic, backed up by Wooting's great software.

The whole thing is remarkably solid, too. The upper aluminum plate is tough, the unit itself weighty enough to fell a bison with a well-angled swipe, and the lack of electronics in the light-beam-breaking switches means that throwing in a spare is easy. Even if this weren't a gimmick carrier—and after our time with it, we're not so sure it is—we'd give it huge credit for its understated tenkeyless looks, underpinned by per-key lighting. Or we would, if it weren't so expensive. $140 is an astonishing ask for a keyboard. We understand where the fee comes from, given the no-compromise internals, and the fact that Wooting is still a small company after its initial Kickstarter success. If you're not going to exploit the analog keys for all they're worth, there's a ream of other keyboards that will sting your wallet less—but we'd still choose a Wooting One. **–ALEX COX**

VERDICT **9** KICK ASS!

Wooting One

WOOT Excellent key feel; neat analog settings; great lighting; solid construction.

TOOT Overly expensive, unless you really need analog.

$140, http://na.wooting.store

SPECIFICATIONS

Switch Type	Flaretech Prism Linear55 "Red"
Form Factor	Tenkeyless
Media Keys	With Fn
Macro Keys	Customizable
LEDs	Per-key RGB
N-Key Rollover	Yes
Pass-Through	No
Dimensions	14.5 x 6.3 x 1.6 inches
Warranty	Two years

Turtle Beach Atlas Three Headset

Bass? What's that?

CAN WE STOP and consider how aggressive this segment of the peripheral market is? The $70–90 headset bracket is the marketplace into which almost every manufacturer wants to get its mitts. After all, most enthusiasts need a decent headset, and for those lacking the eardrums to be able to pick up the refinements of the $150-plus mark, that $80 price tag, balancing quality audio and value, is exceedingly attractive.

HyperX knows it. The impact it had on this segment with its Cloud, Cloud II, and Cloud Pro was groundbreaking, and with the likes of Corsair, SteelSeries, and more following suit, leaning away from RGB and audio gimmicks, and into developing what really matters—audio drivers—it's a market that only becomes harder to get your claws into.

That's a foreboding two paragraphs, so let's get down to it: Turtle Beach's Atlas Three headset is an open-backed conundrum. It features 50mm analog drivers, a plastic outer shell, metal headband, rotatable ear cuffs, memory foam and soft cloth padding (giving it an open-backed sound), integrated auto-volume controlling mic, and a mini amplifier embedded into the cans, with three preset EQs to improve the audio. All of which is powered by a lithium battery, charged via a micro-USB cable.

Sounds like a fairly inclusive list of features, huh? Well, sort of. Let's start with the most important thing: audio. Are those drivers any good? Short answer: no. This is probably the first time ever in a *Maximum PC* review that we're asking for more bass. Seriously, there's none—it's non-existent, and it really flattens the overall feel of both music and games, removing the edge from your experience. The frequency response is just bizarre—this isn't a reference sound, that's for sure. Usually, we scold manufacturers for making headsets too "gamery"—the bass muffles everything, and kills the treble. In this case, the complete lack of bass is just harrowing. On top of that, there doesn't seem to be much clarity in the top end of the treble either; it's just flat and dull, and that's a problem.

TURTLE ECLIPSED

If these were $40–50 headphones, Turtle Beach could possibly get away with it. But when you're in the same bracket as HyperX's Cloud Pro, SteelSeries's Arctis 5, and even Corsair's HS70, all of which command fantastic audio sound stages, you need to be bringing your A-game. Especially when all of those come with a mic, and can be used cross-platform.

Then there's the amp and EQs. First off, can we just say that the benefit of an analog headset is that you shouldn't have to charge it to use it. That's the point. If you're going to add a preamp or EQ wizardry, you ought to be using a USB cable to power it and transfer audio. The fact this preamp comes with a 40-hour battery life, at which point you have to stop and charge it with a 24-inch micro-USB cable, is simply, well, ridiculous.

Plus, the EQs, changeable via a button on the side of the headset, don't seem to affect the sound in any meaningful way. The only one we noticed just slightly increased the height on the mids (there's no way of knowing which preset you're in, apart from the number of beeps it makes when you press the button). That aside, does it do the job? Does it amplify these cans and make them louder than our default pair of testing headphones? Not as far as we can tell. Because of that lack of bass, they sounded quieter overall, compared to our Clouds.

Surely there must be some positives? Well, yeah—the included 3.5mm analog splitting cable is nice, and being able to adjust the earcups to fit your ears is pretty good, too. Oh, and the mic does its job. But they simply don't warrant that $80 price tag. The Atlas Threes are a hassle, another device to charge, with poor audio quality, and features that seemingly don't produce any tangible benefit, or improve your experience in any meaningful way. **–ZAK STOREY**

VERDICT 5

Turtle Beach Atlas Three Headset

OOMF Cables are nice; it does produce sound for 40 hours.

HUSH Audio quality; preamp; EQs do nothing; 40-hour battery life on an analog headset.

$80, www.turtlebeach.com

SPECIFICATIONS

Driver Type	50mm dynamic neodymium
Frequency Response	20Hz–20kHz
Design Style	Open
Microphone Type	Omni-directional
Connectivity	3.5mm analog

Fnatic Flick2

An esports mouse that levels the playing field

DOES THE EXCITING RGB-lit world of esports really need its own line of special toys? Is the smug-faced endorsement of *Heroes of the Storm* pro "Quackniix" on the side of the box really something that will sell mice to people? As much as we might struggle to look at the current esports scene without recalling the rise and fall of the dismal first wave, the money and numbers involved in events such as The International—which, this year, hit a prize pool in excess of $25 million—gives today's electronic sportspeople some serious credibility. So maybe it'll work. But this mouse, from the "gear" department of pro esports team Fnatic, has some big checks to cash if it's going to get past us.

By way of comparison, we put it on the desk directly next to the Cooler Master CM310, a similarly symmetrical gamepointer that we scored 7/10 back in issue 156. Side by side, the Flick2 doesn't make the best first impression; it lacks a lot of the gaudy lighting you might expect from a gaming peripheral, relegating the custom aspects to a couple of highlight spots. It's marginally longer, too, which is a surprising but not altogether idiotic design decision—the longer the mouse, the larger its running surface. And flipping the Flick over to reveal its orange underbelly reveals that Fnatic has taken its surface seriously, endowing this mouse with huge running pads, and making it one of the slipperiest mice we have ever encountered.

But the criticisms we had against the CM310 are, in many ways, amplified in this mouse. We moaned that it was too light, and felt flimsy; the Flick2 is even lighter, presumably to keep the responsiveness high while protecting those limber (and no doubt priceless) esporter wrists. The switches here feel, and sound, similarly cheap, though they take a notable amount more force to depress than the CM310. And both mice subscribe to the "ambidextrous" design that really only works for lefties if they can somehow claw one of their fingers into pressing the left-only side buttons.

There are even things in the Flick2 that are objectively worse than the mouse we've picked as its rival. There are fewer buttons, dropping from three below-wheel controls to one. There's no textured silicon grip on the sides, though Fnatic has opted for a stippled, rubbery finish on each edge that does almost the same job. We trust the marginally thinner cable marginally less than we did Cooler Master's. Considering this is twice the price, that's disappointing.

SENSOR SENSITIVITY

But for all that, the Flick2 does the right things right. The sensor, the beating heart of any mouse, is perfectly tuned, and can be, if you choose, outrageously sensitive. There's customizable lift-off sensing distance, which should suit any play style. Fnatic's software makes it damn easy to configure every aspect of the mouse's behavior, and it's as accomplished as any other in the field. The two side buttons have a decent amount of travel, so they're not easily mis-clicked, and they're absolutely massive, so they're easily found by your thumb. And the notched scrollwheel is both grippy and stiff—how long have we waited for a scroll wheel with definite action and a decent level of resistance? Far too long.

Perhaps this mouse is perfect for esports players. Perhaps. We're still waiting for that lucrative pro contract, so we can't say for sure. But we see it almost as a mirror of esports games themselves. Most popular titles don't need the absolute best hardware to run, because they're meant to be inclusive and solid, whatever the platform. This isn't an exciting mouse, it's not one that's packed with flair, but it's functional where it counts, and the aspects it's lacking don't do anything to stop you waggling it around your desk and clicking. More macro buttons, or more of those extreme harsh edges, or more on-board controls? Those would make this a worse mouse for esports, not better. **–ALEX COX**

VERDICT **7**

Fnatic Flick2

SQUARED No-nonsense design; heavier buttons and wheel; excellent sensor.

IMPAIRED Quite basic for the money; not ambidextrous.

$60, http://fnatic.com

SPECIFICATIONS

Sensor	Pixart
Sensitivity	12,000 CPI
Sensor Model	Pixart 3360
Polling Rate	1,000Hz
Programmable Buttons	Yes
LEDs	RGB
Cable Length	6 feet
Weight	3.28oz

Be Quiet! Silent Base 601

A case study in combating successful Swedish design

WITH REGARD to system building, it almost always comes down to two trains of thought. The first is about showcasing. Presenting your components in a chassis that fits the bill, with LED lighting, tempered glass, reflections, you name it. The second is about sophistication and elegance. It means keeping things out of the way and—more importantly—minimizing noise. More often than not, the latter ethos is associated with workstations in noise-sensitive environments, or for people who simply prefer to enjoy their PC in silence. Fractal Design was the one to look out for as far as that was concerned, with its Define series of chassis being legendary for encapsulating those principles.

For the longest time, the Swedish designer had no competition, because although there was no lack of manufacturers developing quiet components, few had attempted to build a case capable of fulfilling the same noise-reducing remit. Enter Be Quiet!

Although this isn't the first time we've seen a chassis from Be Quiet!, we haven't encountered one aimed at a more budget-oriented portion of the market before. And, boy, does it impress.

The Silent Base 601 is available in three separate color schemes (orange, black, and silver), and comes in either a windowed or non-windowed variant. Ours, the non-windowed variant, is a beauty to behold. The exterior is clean, with subtle accents, and plenty of noise-dampened air vents lining the front panel and roof. There's support for up to two 140mm fans in the front, or three 140mm fans in the roof, and radiator support for both. Be Quiet! has also included two of its Pure Wings 2 140mm fans as standard, as opposed to a cut-down reference variant. There's a fan controller baked into the top of the case, and easy radiator installation in the roof, thanks to a removable sliding bracket, similar to what Phanteks first introduced with its Evolv lineup.

It's when you get to the noise dampening that the Silent Base becomes particularly impressive. Each panel (front, top, and both sides) is lined with half an inch of noise-dampening material, designed to reduce vibrations from inside the case. Then there's the included 3.5-inch hard drive cages, each housing rubber mounting grommets for your old-school spinning drives, further reducing vibrations. Even the air intakes are specially designed to reduce overall noise, by rerouting the airflow around the side of the fan. Bring all of this together, and what you're left with is an incredibly clean, exceptionally quiet case, at a reasonable price point.

Outside of the noise reduction, there's also a ton of modern features packed in. From the vertical GPU mount, to the PSU shroud, housing mounting for a single 140mm fan, and the modular support for even more drive caddies, this thing's a beast to build in.

So, what are our criticisms? Well, if we're honest, we would have loved to have seen more care lavished on the front I/O, because it still looks a bit too in-your-face (especially the power button) for us to really consider it a super-premium solution, along the lines of Fractal. But perhaps that's what Be Quiet! is going for. After all, you do need something to differentiate yourself from the competition. We'd also have liked to have seen a radiator bracket in the front, similar to Corsair's 500D.

That said, the Silent Base 601 is a fantastic new product, and for those looking to build a clean, quiet build, at an affordable price point, it's well worth considering. Ultimately, whether you choose a Fractal case or this will come down to personal preference, but in our eyes, they're very much on a par with one another, which is why we're happy to give this a "9." **–ZAK STOREY**

VERDICT 9

Be Quiet! Silent Base 601

LIBRARY Strong price; easy to build in; good cooling support; innovative features.

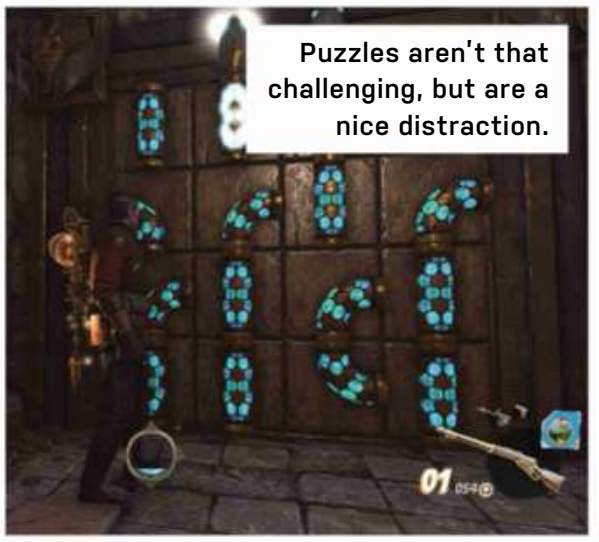
SONIC BOOM I/O requires work; needs another bracket.

$130, www.bequiet.com

SPECIFICATIONS

Form Factor	Mid-tower
Motherboard Support	EATX, ATX, mATX, ITX
Colors Available	Orange, black, silver
Window Available	Yes
3.5-Inch Support	7
2.5-Inch Support	13
Radiator Support	360mm roof, 280mm front, 140mm rear
Fan Support	3x 140mm roof, 2x 140mm front, 1x 140mm rear
Dimensions	20.23 x 20.94 x 9.44 inches
Graphics Card Clearance	17.67 inches
CPU Tower Clearance	7.28 inches
Weight	24.74lb

Special weapons, such as this blunderbuss, give huge firepower but can't be reloaded.



Puzzles aren't that challenging, but are a nice distraction.

Ancient dry bandages are incredibly flammable.

Strange Brigade

The British Empire goes to war against the undead

THE FACT THAT the British Empire hosted an international team of paranormal troubleshooters—emphasis on shooters—is unrecorded in the history books. Thanks to Rebellion, then, a developer whose commitment to historical accuracy cannot be questioned, especially after the testical-shooting gratification of *Sniper Elite,* for bringing it to light.

Strange Brigade is a co-op shooter pitting you against swarms of Egyptian-themed zombies, and as such loses something if played solo. It's also aggressively British, with three of the initial four characters coming from the heart of the Empire, while the fourth, a bit of a stereotype, is from a colonized country. A pre-order exclusive extra character adds diversity, while the first DLC character—an all-American rodeo rider—has already been announced.

The game seems designed to drain your wallet, as the trickle of free extra maps is dwarfed by the "season pass" content, available for a few bucks each.

There's a plot of sorts, with mysterious goings-on in Egypt and missing archaeologists becoming a case for the Strange Brigade. The team's attitude to the undead is to shoot them in the head first and ask questions later, which is just as well, because they come in thick swarms, propelled by the magic of a reincarnated death goddess.

Each character carries an amulet that is powered up by the souls of the newly re-dead, and can release a slightly disappointing area-of-effect attack, which varies from character to character. More effective are the recharging grenades, which can rain fiery extra-death on the hordes every 30–40 seconds. Weapons are limited at first—of course, there's an extra weapons pack for a small fee—but are upgraded with gems, if you find them.

One character—the professor—is better at finding treasure than the others, so becomes essential if you're looking to make money. Chests open for a financial contribution, dispensing secondary weapons that are highly effective, but impossible to reload. Solo players, already penalized for trying to play a co-op game alone, have to spend additional time hunting along all the multiple routes through the levels, though the timing-based puzzles that must be solved to progress make allowances for running speed. Some AI bots to help you out would have been a nice touch, as would the inclusion of split-screen co-op—the latter very much out of fashion, as it not only takes more resources to run on the host PC, but being online only, forces all players to buy their own copy of the game.

Battles come down to arena fights against the undead, who pour through every entrance. The area-of-effect weapons and environmental hazards, such as suspended spiked logs and whirling death blades, make thinning out the numbers easier—as does the tendency of ranged enemies to stand next to explosive barrels, something that has quashed many a videogame civilization.

Strange Brigade is begging to be played in a party of four, but even two friends can have a blast taking down the mummified menace. It's bare-bones for now, but repeated play to power up and swallowing some DLC should make for a compelling co-op experience. **–IAN EVENDEN**

VERDICT 7

Strange Brigade

STRANGER Frantic shooting; good co-op; flow of new stuff.

DANGER Not so good played solo; lots of paid-for DLC; feels incomplete.

RECOMMENDED SPECS Ryzen 1500X/Core i7-3770; 8GB RAM; RX570/GTX 1060.

$50, www.strangebrigade.com, ESRB: T

Photo mode lets you pause the action and spin the camera around.

Lara's expression can be changed for photos, causing much hilarity.

This T-rex skeleton is surely a call back to previous games.

Being a dark game, splashes of light are all the more welcome.

Shadow of the Tomb Raider

Temples of doom abound in Lara's last quest (for now)

HAIR HAS COME A LONG WAY in videogames since the blue-topped goons of *Wing Commander II.* While it still clings in shrub-like patches, it moves and reacts with a degree of naturalism—even if it now protrudes over Lara Croft's forehead like the rearward part of a duck.

Lara's appearance has been tinkered with again. She remains a reasonably naturalistic early-20s woman, as seen previously in the trilogy, but distinct from her appearance in the recent movie. Her body count is mind-boggling, and she must surely be on some sort of most-wanted list for the number of antiquities she's stolen, but her slight figure, noticeably shorter than the heavily armed men who hunt her down, is an effective device for gaining the player's sympathy.

But it's not enough. *Shadow* has done little to fix the problems of the previous two games. For all its similarities to 2015's *Rise of the Tomb Raider*, it still feels like a series in search of an identity, with a cold, unapproachable lead. We tend to look at it as an exploration and puzzle game with combat bits, as it's at its best when Lara is leaping and flipping across chasms, or clinging by her fingernails to crumbling walls. Happily, *Shadow* has dialed the combat back in favor of jumping and pushing things, but it's not without its failures. Early on, there's a section with moving platforms in which Lara needs to swing from street lamps. Many times she crashed to her death, having not even attempted to grab the lamp, until we managed to jump from just the right spot.

The plot is still the sort of nonsense that might be declared unrealistic by even *Assassin's Creed's* developers, but there is a hint of an interesting direction when Lara's obsession with beating the shadowy organization Trinity gets the better of her, and she accidentally unleashes a South American apocalypse. A charming flashback with a devastating ending takes us to the root of Lara's daddy issues, and there are other flashbacks in the form of outfits and even character models from earlier *TR* games.

There are sections in which you're not sure if you're in control, a symptom of the often HUDless presentation that sees cutscenes segue into gameplay with no clear border. Then there was a technical problem that saw the game drop into silence, despite the menu screen having a full complement of music and jungle noises. We put on the subtitles and kept going, but it feels strange playing a game with nothing but the ringing in your ears for company, the controller rumbling in our hands, as we quietly machine-gun a bad guy. It's not a recommended experience, and it's not fair to the game, as the jungle soundscape is highly atmospheric.

Graphically, the Peruvian setting is remarkable, all keenly realized plants, jaguars, and howler monkeys, and Lara explores it clad in highly detailed cloth textures. Her friend, Jonah—although how good a friend she is to him is debatable, as she replies to his asking if she's OK with "Help me with this"—is as devoted as ever, and seems similarly skilled at stealthy killing. But despite its sharp looks, a morose, guilt-ridden Lara makes for a gruff game. Even the ability to give her a smile in the photo mode can't lift it out of its doldrums. **–IAN EVENDEN**

VERDICT 7

Shadow of the Tomb Raider

ENTOMBED Gorgeous jungle environments; inventive puzzles; stealthier combat.

DOOMED Still too much shooting; Lara has become hard to care about.

RECOMMENDED SPECS i7-4770K/Ryzen 5 1600; 16GB RAM: GTX 1060 6GB/RX 480 8GB.

$60, http://tombraider.com, ESRB: M

LAB NOTES

ZAK STOREY, DEPUTY EDITOR

Stagnating Development

Have we reached a new Dark Age in technological progress?

AS SOON AS THE FIRST RUMORS started circulating concerning Intel's top-end 9-series chip, housing eight cores and 16 threads, I knew that it was going to have a soldered IHS. I remember the conversation I had with Alan at the time: There was simply no way that architecture could take another two cores in a single die, without improving the putty-like TIM (Thermal Interface Material) Intel was using between the die and the heatspreader. Lo and behold, we receive a sample, and that's exactly what the company has done.

Considering that this TIM and core count upgrade is the only new addition to the Cannon Lake series (apart from even more BS when it comes to Intel's now legendarily convoluted naming schemes, of course), it's really difficult for me to get excited about it. I've driven the point home enough by now, but to reiterate: Kaby Lake was realistically the only optimization that Sky Lake received. Coffee Lake was simply a slightly higher clocked Kaby Lake with more cores, while Cannon Lake is nothing more than Coffee Lake with extra cores and a better TIM.

Intel's biggest roadblock right now is getting to 10nm. Which is why we've seen a four-year delay on this die shrink alone. But the fear, for me at least, is what can follow 10nm? Manufacturers are already struggling to get to 10, with even GloFo pulling out of the race. What's next for Intel's long-term strategy? Are we going to be in a situation where it's another five years of the same architecture, with diminutive increases in performance, and excessive hikes in thermal output? I certainly hope not....

The only thing I'm vaguely excited about is the packaging.

ALAN DEXTER

Executive Editor

We need to have a word about LEDs, and their prevalence with gaming brands. For a long time, we resisted the excitement around them, because they don't do anything where it matters most for us: performance. Still, even I'm a sucker for a good-looking, well-put-together system, so they definitely have a place. Question is, how should we rate such aesthetics?

The industry has largely taken this out of our hands, by not giving us the option to have gear without LEDs. If you don't like them, turn them off. Frustrating, but it does give you something to tinker with....

Personally, I don't care for LEDs; that's partly due to how my various machines are positioned. The one in my home den is essentially hidden out of sight, so it's irrelevant what it looks like. My main office PC is on a stack of drawers off to one side, so while it is visible, I tend to look at the screen, rather than gaze at its innards all day long, so I'm not too bothered here either. Possibly more relevant is the fact that I don't care what my avatars look like in games. While my peers spend ages picking a particular look in their favorite games, I tend to hit "Random," and go with it. They merely serve as a distraction from what the game is actually about. Maybe all those LEDs are lost on me for the same reason.

Editors' Picks:
Digital Discoveries

Bo Moore, hardware lead, and Jarred Walton, senior editor, reveal the tech that gets them most excited

INTO THE BREACH

I can't stop playing *Into the Breach.* This turn-based strategy from the makers of *FTL* launched in February for PC, but I didn't pick it up until it came to Switch in late August. (I know this is *Maximum PC,* but it is on PC, so bear with me.) Either way, now I can't put it down.

The game distills turn-based strategy to a simple formula: You control three mechs on a eight-by-eight grid, defending a handful of structures from an overwhelming alien assault. You're typically outnumbered and outgunned, but the scales tip back in your favor for one simple reason: You can see every action the enemies will take on the next turn, and exactly how it'll play out. Using that knowledge, you must plan your actions carefully—I often spend 5 or 10 minutes just staring at the map, calculating every possible outcome.

Sometimes the best outcome means throwing your mech in front of enemy fire, or sacrificing a house so that an apartment building might not crumble. But finding that perfect solution—the one that keeps all your mechs healthy, every building standing, and every alien blasted into dust—is one of the greatest satisfactions I've experienced lately.

INTEL CORE I7-9700K

For many tasks, I love using a processor that provides more cores and threads. But for gaming, especially if overclocking to 5GHz or beyond, Hyper-Threading and SMT aren't always beneficial. Intel's 9th Gen Core i7-9700K makes the interesting move of disabling Hyper-Threading but adding two cores, resulting in an eight-core/eight-thread processor. It's a net win for performance, especially once you factor in clock speeds.

The price is about the same as the previous-gen i7-8700K, and it even works in the same mobos. The Core i9-9900K is faster in heavily-threaded workloads, but for gamers, I think the i7-9700K is the better buy. One thread per core means more L2 and L1 cache for that thread, and I still haven't seen any games that consistently use more than eight threads.

I'm also stoked about Intel's return to a solder TIM, which boosts clocks by around 400MHz compared to 8th Gen CPUs. If you want to build the fastest dedicated gaming PC possible, the i7-9700K wins every gaming benchmark I've run, and it beats the i7-8700K in every test. Overclocking sweetens the deal; it looks like 5.3–5.4GHz with a good liquid cooler will be typical.
$374, www.intel.com

TP-Link 10,400mAh Power Bank

I'M AN OUTDOORSY kinda guy. There's nothing I love more than being out there in the elements, camping, mountain biking, or hiking. Getting out of the big city into the wilderness is heaven.

Yet I'm still a techno geek. Being a tech journo, you're perpetually on call, so having a fully charged smartphone is essential. There is no shut-off switch in this profession. On top of that, my hobby's pretty technologically demanding, too—from my Garmin Edge 820 bike computer I need to keep charged, to the GoPro Hero5 I slap on my chest, having access to some form of power is vital.

For me, that problem is solved by TP-Link's battery banks. I currently use two: the 10,400mAh TL-PB10400, pictured above, and the 15,600mAh TL-PB15600.

The former is the one that comes with me most often. Thanks to its super-small form factor, I can throw it in a backpack or pocket, and run the cable straight to my phone to charge it on the move. It comes with two USB 2.0 ports, a battery level indicator, and a handy little LED torch. There's some serious tech in here, too, with short-circuit, over-volt, over-charge, and overheating protection.

I've had the 10,400mAh product for three years, and it's more than made up for the initial cost—that's why I bought the 15,600mAh one, too. I advise going to www.bhphotovideo.com to grab one—it's the cheapest place I've found it online.

If you're on the move, and need a battery bank, I can't recommend TP-Link enough. **–ZS**
$30, www.tp-link.com

LETTERS

WE TACKLE TOUGH READER QUESTIONS ON...

> Monitor Options
> Noise Reduction
> Laptop Reviews

Value Screening

Your article on "The Ultimate Build Guide," October 2018, could not have been more timely for me. It's been 15-plus years since I built my own PC, and I am looking to get back into it with a cheap, but powerful, build. The only thing lacking for me in the guide would be an affordable monitor to go with the new rig. Do you have any recommendations for monitors under the same theme as "most bang for your buck"? Thank you.

–Jeremy Knox

DEPUTY EDITOR, ZAK STOREY, RESPONDS: There are plenty of excellent monitors out there right now, and you should be able to find a great value screen whatever size you're looking for. For those wanting a specific recommendation, though, we'll point you toward this monitor on Amazon (although, obviously, other outlets are available): www.amazon.com/dp/B072M34RQC. This Full HD 23.8-inch IPS screen from HP currently only costs $110, and is worth grabbing if you don't need anything bigger or boasting a higher resolution.

Generation Gap

I was looking at an old Dell that had a Core i5-3570, and noticed that it had very similar specs to the Core i5-7500. The only differences are the amounts and types of memory supported, bus speeds, and lithography. I found that strange, given there are four generations between them. What gives? Would those differences have a noticeable effect on performance? Would the Core i5-3570 bottleneck a GTX 1050 Ti compared to the Core i5-7500? **–Rhye**

EXECUTIVE EDITOR, ALAN DEXTER, RESPONDS: These chips may be four generations apart, four years apart, use different production processes, and support different memory standards, but you're right, the headline figures really aren't too different. Both CPUs are four-core, four-thread, mid-range offerings, with a nominal frequency of 3.4GHz that turbos to 3.8GHz. The Core i5-3570 was released back in 2013 using the Ivy Bridge architecture and supporting DDR3, while the Kaby Lake-powered Core i5-7500 came out in 2017 and supports DDR4.

The memory subsystem is the biggest difference. Paired with a GTX 1050 Ti, you're probably only looking at 10 percent in real-world testing. If you're building from scratch, we'd recommend the newer chip, but if that old Dell is going cheap (or you already own it), there's nothing wrong with giving it a new lease of life with a GTX 1050 Ti.

Silence is Golden

I have a suggestion for a future article: Techniques and recommendations on minimizing your PC's noise. The article would explain what to look for when purchasing case fans, CPU coolers, fan connection and control methods, rubber grommets, sound-proofing panels, CPU fan versus liquid cooling, and so on. The article may include recommendations for top-rated quiet products, such as cases, fans, CPU coolers, GPUs, and so on. Lastly, the article would test the impact of these quiet components, and the methods of silencing through software and physical upgrades.

Just an idea I'd like to see. I've been a subscriber for eight years, and love your magazine. If this article has been published before and I missed it (or forgot about it), please let me know which issue it's in.

–Dave Ordway

EXECUTIVE EDITOR, ALAN DEXTER, RESPONDS: This is something we've done in the past, but it's worth looking at again, as a lot has changed, and we've got at least three new generations of hardware to try to keep quiet again. The prevalence of all-in-one coolers, combined with some hot, hot hardware, should make for some interesting compromises. Watch this space.

Compact Choices

I have been subscribing to *Maximum PC* since 2006. It's a great magazine, and it has helped me in my desktop builds. I have been building and upgrading desktops since the days of the 286 PCs. I have recently begun to

↘ submit your questions to: comments@maximumpc.com

purchase laptops, and I was wondering if there was a plan to add laptop reviews to your magazine to match the "Budget," "Mid-Range," and "Turbo" builds for desktops? It may not be feasible to add this to your magazine on a monthly basis, but could it be added on a quarterly or semi-annual basis? There are so many laptops on the market, I for one would like to see laptops rated as the "Best Budget," "Best Mid-Range," or "Best Turbo" for future purchases.

–Robert Drumheller

EXECUTIVE EDITOR, ALAN DEXTER, RESPONDS: Value is a core consideration when reviewing laptops, and it's something that is already taken into account for every review. This being *Maximum PC,* we do tend to look at more high-end "Turbo" and mid-range laptops, than budget offerings, but it's a reasonable enough idea, and we will bear it in mind going forward.

Self-Maintaining

Chris Lloyd's article, "The Rise of the Learning Machines," was excellent. More of these articles would be welcome, such as the previous month's article on general purpose GPUs (GPGPUs).

Regarding his statement, "Perhaps one day we will have a version of Windows that can detect and correct bugs as it operates," I know he was writing about general defects, for which auto-correction is some time off. However, in the domain of security bugs, any operating system with an anti-malware package is detecting and correcting, or at least mitigating, bugs. And some such packages use machine learning today. **–Robert Tortorelli**

EXECUTIVE EDITOR, ALAN DEXTER, RESPONDS: Good to hear you're enjoying these more thought-provoking reads, and our intention is to do more of them along the way. As for your point about anti-malware packages producing a reasonable attempt at self-correction, the end result may be similar, but the core philosophy is quite different, and the future that the article was suggesting was more excited about the idea of the operating system being aware enough to correct core functionality that has bugs, rather than responding to external threats—although this is something it could do as well. In many ways, this may be a scary prediction, but as software gets more and more complex, it is something that we could see happening.

[NOW ONLINE]

HIT 60FPS IN ASSASSIN'S CREED ODYSSEY

Assassin's Creed Odyssey is one of the best games in the series, with many improvements to the formula that keep it interesting. It also happens to be one of the most demanding games around when it comes to PC requirements—par for the course for a new *Assassin's Creed* game. You can certainly play it on a modest system—at 30fps (give or take)—but if you're the type of player who likes to dial up the settings to maximum quality, you should prepare for some hurt. Even on the burliest hardware around, such as Nvidia's brand new RTX 2080 Ti, you're not going to hit 60fps at 4K, and at 1440p, you'll still need an RTX 2080 or RTX 2080 Ti.
Read the full article: https://bit.ly/2RIjaKV

Backward-Compatible

In your October issue, a reader, Jeff Goldstein, wrote about an issue he'd had with his B350 motherboard and his Ryzen 5 2400G. As he mentioned, the board had an old BIOS. The real issue wasn't the GPU, it was the generation of the processor. The B350 and X370 chipsets were designed for the first-gen Ryzen chips. The B450 and X470 chipsets are for the second-gen Ryzen chips.

What is nice is that the older boards can work with the second-gen chips if you update the BIOS. That means that you must have access to a first-gen Ryzen chip in order to update the BIOS. Both AMD and I believe the new Intel chips will do this. For Intel, I think that's the word for the 9th-gen with regard to the 370 and 390 chipsets—correct me if I'm wrong. Anyways, everything from PCpartspicker to every PC channel on YouTube has mentioned this requirement. I agree that anything coming direct from Asus should have an updated BIOS, but if you buy it from any kind of retail business, it is unrealistic to think that the board is necessarily a recently stocked item. Because of that reason, you should not assume that the board was shipped after the newest BIOS was created.

I was also surprised when, in the response, none of this was mentioned. Chipsets are the biggest thing on the mobo to research before buying. Compatibility immediately after that. The issue is an annoying one, but one that isn't hidden by any stretch. I hope he got his build up and running, but I am a bit surprised that the real problem that was causing his issue wasn't mentioned.

–Kurt

EXECUTIVE EDITOR, ALAN DEXTER, RESPONDS: This is a potential issue with any backward compatibility, but it's particularly acute in this case, due to the first generation of AMD's Ryzen processors not having integrated graphics, and thus requiring having a graphics card to hand—even if you aren't using one in the actual build. It's something we faced again this issue when building the budget machine for the cover feature, and while we're lucky that we can just grab a different processor and graphics card to get it up and running, not everyone has access to such parts. While you're right that the second-generation motherboards are built with the newer chips in mind, you can still use first-gen boards with them, and indeed due to price differences, you'll often want to. And yes, you can use Intel's 9th-generation CPUs with the last-generation mobos, but these require a BIOS update to do so—in exactly the same way (bar needing a graphics card in most cases).

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THE BUILDS

BUDGET

INGREDIENTS

PART		PRICE
Case	BitFenix Nova TG	$50
PSU	450W Corsair CX450	$48
Mobo	ASRock AB320M-HDV	$50
CPU	AMD Ryzen 3 1200	$129
GPU	Gigabyte GeForce GTX 1050 2GB	$130
RAM	8GB (2x 4GB) Team T-Force Dark @ 3,000MT/s	$75
SSD	120GB Adata Ultimate SU650 2.5-inch SSD **NEW**	$27
HDD	1TB Seagate BarraCuda ST1000DM010 HDD	$45
OS	Ubuntu Desktop Linux 18.04 LTS 64-bit	$16

Approximate Price: $570

LAST MONTH, we gave this machine a major shake-up, and it's performing well, so no need for any radical changes this month. In fact, there's only one change, and that's due to the Kingston SSD we used last month being out of stock. So instead, we've turned to Adata, and its SU650. Not exactly a performance offering, but it's incredibly affordable for a 120GB boot drive, and it's still faster than a traditional spinning drive. With only one hardware change, you'd expect the overall price to remain largely the same, but thanks to a series of price drops, we've managed to piece this machine together for $47 less than it cost us four weeks ago. The biggest money saver was the AMD Ryzen 3 1200, which rolls in $31 cheaper than last time. Obviously, this is a response to the second-gen Ryzen chips now doing the rounds, but it's still a great low-cost CPU, and well worth being the basis of a budget system.

MID-RANGE

INGREDIENTS

PART		PRICE
Case	Fractal Design Meshify C	$85
PSU	550W EVGA SuperNOVA 550 G3 80+ Gold	$77
Mobo	Asus ROG Strix B450-F Gaming	$125
CPU	AMD Ryzen 7 2700	$250
Cooler	Corsair Hydro H100i Pro 240mm RGB AIO	$120
GPU	Gigabyte GeForce GTX 1070 Ti **NEW**	$390
RAM	16GB (2x 8GB) G.Skill Aegis 3,000MT/s	$125
SSD	250GB Samsung 970 Evo M.2 PCIe SSD	$88
HDD	1TB Seagate BarraCuda ST1000DM010 HDD	$45
OS	Windows 10 Home 64-bit OEM	$100

Approximate Price: $1,405

THE SPECIFICATION for our mid-range machine has remained stable this issue as well, with the only change being the graphics card, as we found the Gigabyte card for $10 less than the Zotac we used last issue. At the time of writing, the GeForce RTX 2070 is imminent, but we're not sure how it'll perform in ray tracing and DLSS titles, so we will hold fire on recommending it for now. Of all the RTX cards, this is the one that has the most sensible pricing, so it's worth watching this space. As with our budget build, there's a healthy price drop over last month's system, and once again, it's the AMD processor that brings the biggest saving, at a whopping $40 over last issue. The Ryzen 7 2700 is a second-generation Ryzen CPU, though, so that price drop may just be AMD trying to spoil the launch of Intel's 9000-series chips. It will be interesting to see whether the Core i5-9600 can throw a monkey wrench in AMD's plans next issue.

UPGRADE OF THE MONTH

CORSAIR HS70 SE WIRELESS

We're happy with all these builds at the moment, and think they hang together well enough that we don't need to highlight individual components in this "Upgrade of the Month" slot. Which is why we've elected to focus on a peripheral instead.

Of all the headsets we've seen recently, these wireless cans from Corsair really impress. We have many fears with wireless headsets—sound quality and battery life are particularly sensitive areas—but the HS70s allay them impressively. The soundstage is crisp and balanced, with a distinct lack of the overbearing bass that is common in so-called gaming headsets. There's the added bonus that these look the part, too, with no silly LEDs draining the battery.

On top of all that, they're not stupidly priced, as wireless headsets used to be. Whatever system you're building, do yourself a favor, and grab a good set of cans while you're at it.
$100, www.corsair.com

WE'VE SEEN GREAT SAVINGS on AMD's more affordable processors this month, but the memo clearly didn't reach the Threadripper lines, which haven't seen any price shifts. Still, the 2950X in this "Turbo" build represents impressive value for money, so we see no need to swap it out yet. If you're looking for serious multithreaded performance, you're going to be pushed to come up with anything that can beat the 16-core, 32-threaded monster we have here.

There aren't many changes elsewhere; even fluctuations with pricing haven't had much impact, with the biggest saving appearing on the RAM front (surprisingly), although a price increase on the case wiped most of this out. There were a few savings to be had on the SSD and motherboard, though. As ever, there are bargains to be had on processor, motherboard, and RAM bundles, which are worth checking out at the time of purchase.

A quick look at the overall price will reveal that this machine is $122 more than last month's build, so what gives? The big change here is the inclusion of the GeForce RTX 2080, which costs considerably more than the GTX 1080 Ti we had last month, and is something of a contentious addition, even in the office. The team is split evenly between sticking with the 1080 Ti for now, and saving a big chunk of cash, and those backing the potential of what RTX may bring. Ultimately, it's your call.

For more of our component recommendations, visit www.maximumpc.com/best-of-the-best

INGREDIENTS

PART		PRICE
Case	NZXT H700i	$200
PSU	Corsair RM750X Modular Gold	$100
Mobo	Asus Prime X399-A	$296
CPU	AMD Threadripper 2950X	$899
Cooler	Enermax Liqtech TR4 II 240mm RGB	$140
GPU	EVGA GeForce RTX 2080 XC Gaming NEW	$800
RAM	32GB (4x 8GB) G.Skill TridentZ 3200	$302
SSD	512GB Samsung 970 Pro M.2 NVMe	$198
HDD	2x 2TB Seagate BarraCuda ST2000DM006	$120
OS	Windows 10 Home 64-bit OEM	$100
Approximate Price:		**$3,155**

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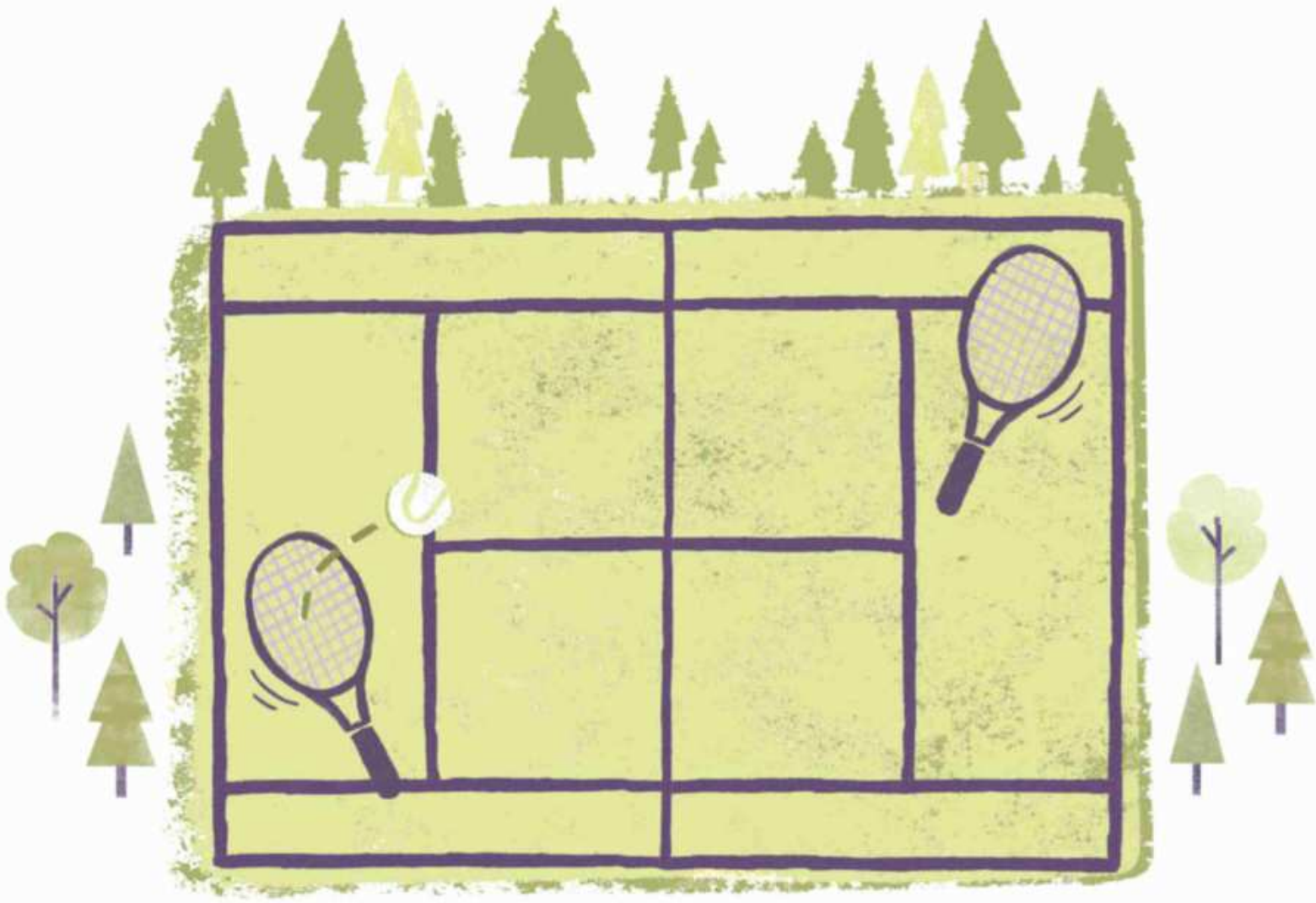

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